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Alberta. Environment Council of Canada.
THE IMPACTS OF LINEAR DEVELOPMENTS, RESOURCE EXTRACTION,
AND INDUSTRY ON THE AGRICULTURE LAND BASE. 1982.

LINEAR DEVELOPMENTS, ACTION, AND INDUSTRY GRICULTURAL LAND BASE

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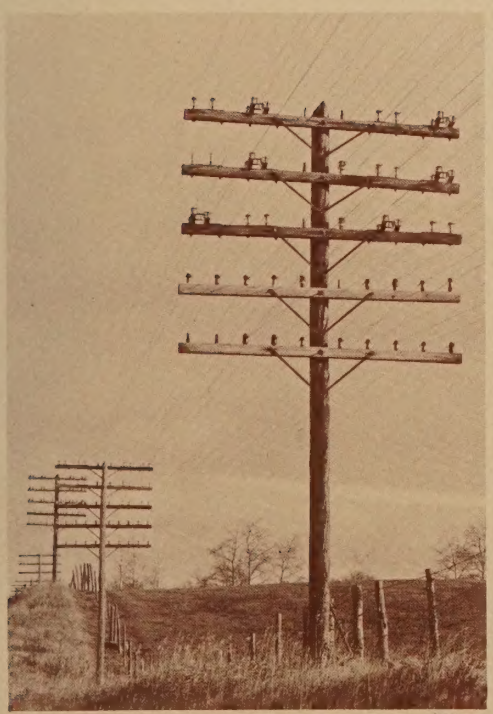

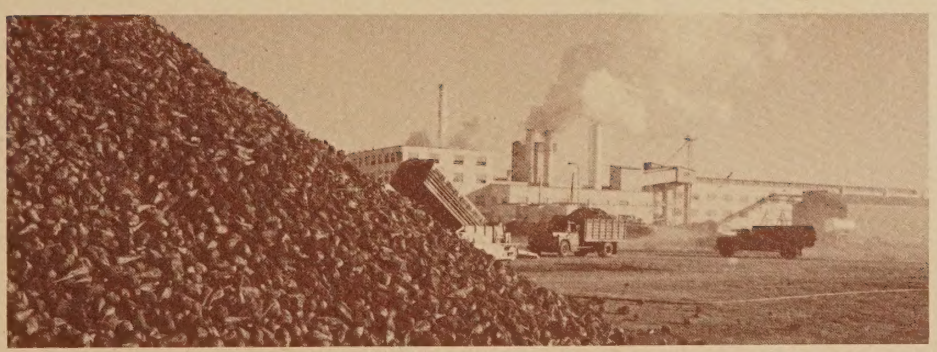

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The Impacts of Linear Developments, Resource Extraction, and Industry on the Agricultural Land Base

October 1982

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Environment Council of Alberta

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This report may be cited as:

Webb, C. 1982. *The Impacts of Linear Developments, Resource Extraction, and Industry on the Agricultural Land Base.* ECA82-17/IB25. Edmonton: Environment Council of Alberta. 87 pages.

ECA82-17/IB25

PREFACE

In recent years, the Environment Council has become aware of a number of concerns about the long-term security of the agricultural land base. An in-depth look at the present status of the agricultural land base, and at impacts that may affect the land base in the future seemed warranted. Accordingly, the Environment Council is investigating this important topic.

Since settlement of this province began, farming and ranching have been important aspects of life in Alberta. Agricultural land dominates the landscape in central and southern Alberta, as rich farmlands stretch to the horizon. Throughout the years, breaking of new farmland has continued at the fringes of settled areas, and land has been improved for agricultural use. The land base used in agriculture has increased, as have yields and production of crops. Agriculture has become an integral part of the social and economic fabric of Alberta.

In recent years, however, some concerns have been raised about the long-term security of the agricultural land base in Alberta. As the province grows, more land is needed for housing, transportation, and recreation. The amount of new land available for agriculture is limited. Resource extraction is expanding rapidly. Some farming practices, such as summerfallowing, may be affecting soil fertility or land productivity. The acreage of land affected by salinization is increasing. Other activities, within or outside farming, are also having an impact on agriculture. The effects of each may be small, but evidence has been mounting that the cumulative effects may threaten the security of the agricultural land base itself.

In general, there appear to be three types of concerns:

1) loss and fragmentation of agricultural land
2) impacts on the capability of the land to produce agricultural products
3) impacts of other activities that influence the effectiveness and efficiency of agricultural activities.

The effects on agriculture can be direct, as in the loss of land, or indirect, as in the loss of service industries in a rural area. Some of these threats come from outside the agricultural industry, while others arise from agricultural activities and practices themselves.

The Environment Council investigation will examine the types and magnitude of perceived threats to the security of the agricultural land base and will speculate on some implications for the future. Problems for agriculture will be identified and discussed in light of what is being done about them now and what could be done about them in the future.

A series of reports has been prepared for this investigation. Some of them present background information which sets the stage for further examination of the subject. Other reports look at the three types of concerns outlined earlier. These reports are intended to provide information to stimulate public discussion about the security of the agricultural land base. It is anticipated that public hearings on this topic will provide an opportunity for Albertans to air their concerns, confidence, pessimism, or optimism about agriculture in Alberta.

This report examines the impact of linear developments, resource extraction, and industry on the agricultural land base. In the report there is discussion of both direct and indirect impacts on the land base, relevant legislation and policies, and the feasibility of alternatives which could mitigate impacts. Not every type of linear development, resource extraction, or industrial disturbance is discussed. This report deals only with those types of disturbance about whose impact on the land base there is widespread concern, and for which there is sufficient information to generate discussion.

Throughout the report there are terms (in italics) with which the reader may not be familiar. These terms are defined in the glossary at the end of the report.

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SUMMARY

Transmission Lines

There are 97,000 miles of power lines in Alberta, most of which are in the White and Yellow areas of the province.

Transmission towers on cultivated farmland increase the cost of farming. The increase results primarily from extra time needed to farm around the towers, and from the extra cost of weed control around the towers. The costs of farming around power line structures are higher in irrigated than in dryland fields.

Physical and possibly biological effects created by very high voltage transmission lines may be annoying or hazardous to farmers living or working near the lines.

The extra costs of farming near transmission lines depend upon the routes chosen for the transmission lines. Transmission lines which cross fields diagonally present the greatest costs to individual farmers, but the interests of individual farmers may be sacrificed in order to reduce the impact on the larger farming community, if diagonal routes are the shortest ones between two locations. Recent Government of Alberta policy says that farming interests must be taken into account when power line routes are being considered.

A three-fold increase in power demand is expected within 25 years. Some possibilities for minimizing the adverse impacts of transmission lines on the agricultural land base include: generating power closer to the load centre, constructing underground transmission lines, using towers designed to occupy less land, and building higher voltage transmission lines. Few of the alternatives show much promise for use in programs designed to conserve land for agriculture.

Roads

New highways between urban centres may increase the cost of farming by fragmenting farmland.

There are 92,650 miles of roads and highways in Alberta which occupy nearly 870,000 acres of land. From 1976 to 1980, 25,077 acres were used for various road and highway construction activities in Alberta. Most of the acreage used was for new roads and road widening.

Most new road construction (administered by the municipalities) occurred outside the Edmonton-Calgary corridor. In areas where the level of road-building activity was high, about 18 percent of the land used was CLI class 1-3 land. There does not seem to have been a concerted effort to avoid the use of high-quality agricultural land for new roads.

Most of the road-widening activity was outside the Edmonton-Calgary corridor, but 43.1 percent of the land used in the high-activity areas was CLI class 1-3 land. Avoidance of high-quality agricultural land for road widening was not generally apparent.

New highways (administered by the provincial government) accounted for 10.4 percent of road construction activity between 1976 and 1980, and most of the highways were built outside the Edmonton-Calgary corridor. Approximately 38 percent of the land converted in the high-activity areas was CLI class 1-3 land. Generally, rates of use of high-quality land for the construction of new highways were not inordinately high.

Of all the road and highway construction activity between 1976 and 1980, highway widening used the least amount of land. Most of the highway widening was outside the Edmonton-Calgary corridor. Except in the corridor area, CLI class 1-3 land was avoided in the highway-widening process.

High-quality land was generally used for the construction of public works (rest stops, equipment yards, and so on). Most of the land used for public works was outside the Edmonton-Calgary corridor.

Alberta Transportation may incidentally conserve some agricultural land by exercising some of the planning options available to it. Reduced user demand is probably the best way to minimize the use of agricultural land for roads.

Pipelines

There are approximately 112,000 miles of oil, gas, and other pipelines in Alberta.

Land is disturbed when pipelines are installed, but the resultant harm to the land base appears to be minimal when appropriate reclamation practices are followed.

Pipeline spills are probably more harmful to soil productivity than pipeline installation. The total farm acreage affected by pipeline spills each year is small. The impact on the affected land, however, may be great due to the toxicity of some of the spilled hydrocarbons; poor infiltration of water into the soil; poor aeration of the soil if water does infiltrate into it; and nutritional deficiencies in the soil, caused when soil micro-organisms, which multiply rapidly as they use the oil as a carbon and energy source, also use soil nutrients.

Surface oil spills can be reclaimed by fertilizer applications and cultivation. Salt spills can also be reclaimed. If the oil spill is underground, or if the spill also contains brine, spill reclamation is more difficult.

Utility Corridors

Multiple-use corridors could reduce some of the problems associated with single-use corridors. Some advantages of multiple-use corridors would be reduced fragmentation of agricultural land, and faster acquisition of rights-of-way.

Some disadvantages of multiple-use rights-of-way are: agricultural operations within them are severely disrupted, facility owners have to spend more time planning their activities within the constraints of other facility owners, and serious disruptions of supply can result from vandalism, storms, civil disturbance, and so on.

Questions about time, location, and demand of future activities cannot be answered with enough certainty to designate a network of corridors in Alberta. Multiple-use corridors known as Restricted Development Areas are, however, found near Calgary and Edmonton.

The Energy Resources Conservation Board has expressed misgivings about multiple-use corridors. Recent Government of Alberta policy has stated that there will be attempts to minimize the impacts of corridors on the agricultural land base.

Coal Mining

Most of the potentially recoverable coal in Alberta is found within the Plains region of the province. About 10 percent of the ultimately recoverable coal in the Plains region can be extracted by strip mining. Strip mining could affect 384,000 acres of largely agricultural land in Alberta.

Nearly all the coal used in thermal generation of electricity in Alberta is from only five mines. To date, about 7,775 acres have been disturbed by surface mining activity at the five sites. Sixty-three percent of the land disturbed since 1976 has been CLI class 1-3 land.

The Land Surface Conservation and Reclamation Act, and Alberta's Coal Development Policy are intended to minimize the detrimental effects of coal mining on agriculture. The Coal Conservation Act can reduce the impact of mining on agricultural land by ensuring that there is maximum practical recovery of coal from any one area.

Reclamation of mined lands is a way to make Alberta's energy needs compatible with agriculture. Some results have suggested that cautious optimism about restoration of mined lands is warranted. In certain situations, full reclamation of mined lands is difficult because strip mining reduces the capacity of soils to accumulate water, and because reclaimed soils are prone to erosion. Reclamation is more difficult when spoil materials containing salts end up near the soil surface after the mine pits have been refilled. Salts interfere with the

ability of plants to absorb water and nutrients from the soil and, in sufficient concentrations, salts can alter soil structure. Most of the overburden on Plains coal is saline or sodic. The heavy costs of mine reclamation could be covered by relatively small increases in the cost of electricity.

Other reclamation problems such as the difficulty of re-establishing groundwater aquifers and soil stability also exist.

Oil and Natural Gas Exploration and Extraction

In times past, the normal configuration of drilling spacing units and target areas for oil and natural gas wells interfered greatly with farming operations. The increase in time and money needed to farm a field divided by a well site and road was more costly to farmers than was the lost production from the well site and access road.

In 1981, the Energy Resources Conservation Board adopted northeast corner target areas as the normal configuration for oil wells in new oil leases. The adoption of northeast corner target areas will reduce the costs of farming around the wells.

Directional drilling, as a means of reducing the impact of oil and gas activities on the agricultural land base, is not generally warranted. The potential for the use of directional drilling is greatest in the heavy oil areas.

About 274,000 acres of agricultural land in Alberta have been disturbed by oil and gas exploration. Nearly two-thirds of that acreage has yet to be reclaimed. From 1976 to mid-1981, approximately 108,000 acres were disturbed by drilling. Close to 35 percent of the total, 37,647 acres, was CLI class 1-3 soils.

The land use problems presented to farming by oil and gas wells may be compounded by accidental spills of formation fluid. The yearly number and volume of spills is not large. But where such spills occur, the effect can be severe. The presence of salt and, to a lesser degree, hydrogen sulphide in spills has very harmful effects on the soil. Reclamation is particularly difficult where salt is part of the formation fluid.

Industrial Land

Diversification of the provincial economy and decentralization of industrial activity are two keystone policies of the Government of Alberta.

The objective of decentralization is to promote industrialization in smaller centres. The Government of Alberta promotes decentralization by increasing the number of government offices and services, by promoting industrialization, and by funding infrastructures in non-metropolitan centres. Alberta Municipal Affairs has issued a rural industrial land use policy which facilitates industrial development in rural areas. Decentralization may be of limited success because current policies are not designed to restrict growth in urban areas.

The regional planning commissions try to co-ordinate the industrial aspirations of local governments. Conservation of agricultural land by the planning commissions will not be easy, because of the need to also facilitate industrial development.

The total area of industrial parks with some land available for occupancy is approximately 47,500 acres. Only 26,000 acres, however, are now available for use. Much of the land available for use as industrial parks is located in the Edmonton-Calgary corridor, especially near Edmonton. Some data suggests that much good-quality land is being used for industrial purposes.

Thermal Power Generation

Most of the electricity generated in Alberta is coal-generated.

Thermal power facilities in Alberta now occupy about 4,000 acres of land. Up to 14,000 acres could be needed for power plants and cooling ponds in order to meet the power demands of the next 25 years. Fifty-seven percent of the land now used or approved for thermal power plants alone is CLI class 1-3 land.

Sulphur dioxide from thermal power plants can reduce the productivity of agricultural land. Although the sulphur content of Alberta coals is low, increases in the amount of coal burned could increase sulphur emissions to six times present-day levels by 2006, according to one projection.

Other possible adverse effects of thermal power plants include land and groundwater pollution by ash from coal combustion, and pollution of water bodies which receive waste heat from power plants. These problems do not yet appear to be severe.

There do not appear to be many feasible alternatives to the generation of electricity by thermal power plants. There are some options such as the use of cooling towers rather than cooling ponds, reduced use of electricity by consumers, and the use of coal from areas of lower agricultural potential, which could conserve good agricultural land.

Natural Gas Processing and Manufacturing Industries

There are about 400 natural gas processing plants in Alberta, most of which are found in the White and Yellow areas of the province. The leases for the 400 processing plants affect about 35,000 acres. The plant sites occupy about 3,500 acres. Another 25,000 acres of land are being used for the plant sites and buffer zones of industries which use petroleum hydrocarbons as fuel or feedstock.

There are several arguments offered for and against continuing to locate manufacturing plants on good agricultural land.

About one-half of the natural gas already found in Alberta has significant amounts of hydrogen sulphide. Sulphur dioxide is a by-product of the process

of removing hydrogen sulphide from the gas. The sulphur which is deposited on the soil can be converted into other compounds which can reduce the fertility of agricultural land.

A decrease in soil pH is characteristic of soils that have absorbed sulphur. The size and rate of decrease depend upon the buffering capacity of the soil. Small decreases in soil pH can have substantial effects on plant productivity, depending upon the original pH of the soil and the type of crop grown. There is some uncertainty about how long it takes for sulphur emissions from natural gas plants to have a noticeable effect on surrounding soils.

Sulphur released into the environment may reduce the viability of vegetation and detrimentally affect the health of farm animals.

There do not appear to be many techniques presently available for economically reducing sulphur emissions from gas-processing plants. Until such techniques are found, treating the symptoms of sulphur dioxide pollution is probably necessary. Liming acidified soils can restore them to higher productivity.

INTRODUCTION

For many years now, the use of agricultural land for urban development has been of concern in many parts of the world. Urbanization consumes much land in Alberta too. A substantial amount of land is utilized for purposes that are integrally, if indirectly, related to our use of land for urban housing – industry, which employs the residents of housing developments; roads, for access to and from places of residence, employment, and recreation; oil wells from which the fuels for automobiles are extracted. In fact, most facets of our modern existence have an impact on the land base.

This report provides some perspective on problems created for the agricultural land base by urban-related activities. Data on the amount and quality of land used for urban-related activities is provided, since consumption of agricultural land is perhaps the most obvious land use problem. The report also discusses the not-so-obvious extra costs for farming, and the biological effects resulting from the urban-related activities. Brief assessments of the difficulties in reconciling the impacts with the long-term agricultural potential of the land are given. Another major thrust of the report is an examination of the ways in which legislation, policies, and decisions can affect the use of land.

The activities discussed in the report are grouped together into three main categories: linear developments, resource extraction, and industry. Organization of the activities into three main categories, however, is not meant to imply that the activities are isolated in their effect on the land base. In fact, there is often a relationship between categories. For instance, although coal mining, thermal power plants, and power transmission lines are discussed under three different categories, they are sequentially related to each other. Since the relationships among many of the activities are complex, there are probably few fully satisfactory simple ways to conserve agricultural land.

Throughout the report, reference is made to the White, Yellow, and Green areas of Alberta (Figure 1). The White Area is the settled part of the province, and agriculture is the major land use activity there. The unsettled parts of the Yellow Area are considered transition areas which are available for homestead settlement, and have lands primarily intended for agricultural use. The Green Area is basically the non-settled, forested part of the province. Limited grazing is the only agricultural activity permitted in this area.

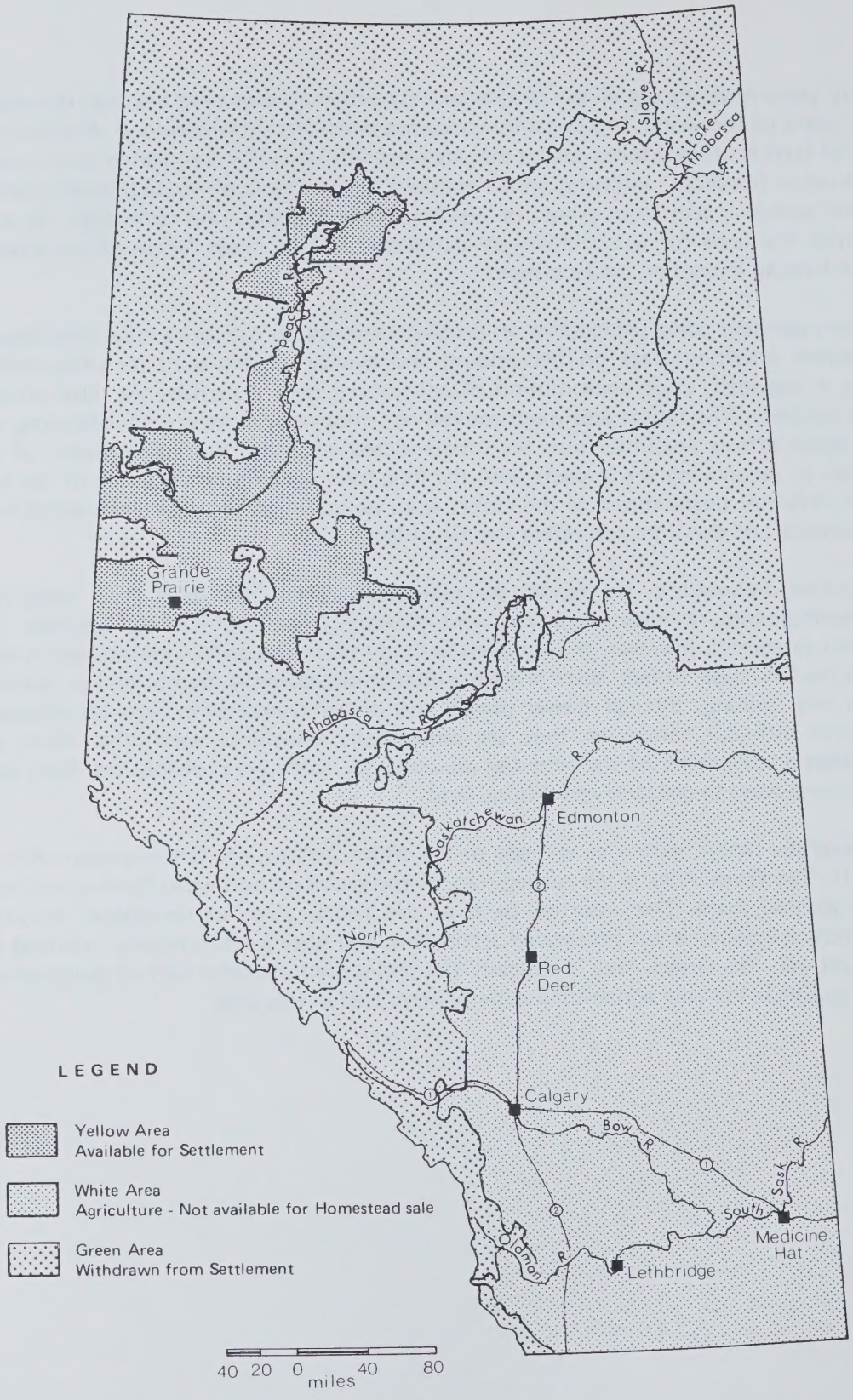

Figure 1. The White, Yellow, and Green areas of Alberta

THE IMPACT OF LINEAR DEVELOPMENTS ON ALBERTA'S AGRICULTURAL LAND BASE

TRANSMISSION LINES

Mileage of Power Lines in Alberta

In 1981 there were 96,827 miles of power lines in Alberta, which can be categorized as follows: transmission lines (over 60 kV) – 9,691 miles, subtransmission and distribution lines (60 kV or less) – 38,175 miles, rural electrification area lines – 42,098 miles, and utility-owned farm lines – 6,863 miles (ERCB 1982a: 29). Data on the length of power lines within the White and Yellow areas of Alberta (the primary agricultural areas) is not readily available. Nevertheless, the rural electrification area lines and utility-owned farm lines, and long lengths of transmission lines, are found in the White and Yellow areas of Alberta.

Most of the power lines in Alberta that follow road allowances do not adversely affect Alberta's agricultural land base. Transmission lines which cross cultivated farmland are the major source of adverse effects on agricultural land.

Extra Costs of Farming Near Transmission Lines

The crossing of farmland by transmission towers is disconcerting to farming interests for a number of reasons. The main reason is that the towers increase the costs of farming. Another is that the base of steel towers precludes a small amount of land from agricultural use. The base of an ordinary 240 kV steel transmission tower keeps about 250 square feet of land from crop use. A considerably larger amount of land, however, is kept out of production because farm machinery cannot operate safely and efficiently next to the tower base.

When a farmer operates machinery around a tower using the diamond method (Figure 2), an area of 1,120 square feet cannot be used for production (McKinnon, Allen and Associates (Western) Ltd. 1978b: 12). By circling around the tower in addition to bypassing it – the complex method (Figure 3) – only 830 square feet are kept out of production (McKinnon, Allen and Associates (Western) Ltd. 1978b: 12). In most cases agricultural lands are traversed by single- or double-pole lines at voltages up to 138 kV. Hanus (1979: 5) estimated that the amount of land kept out of production by a single pole averaged 144 square feet, and by a double pole, 427 square feet. These figures can be used to obtain an estimate of the total amount of land removed from agricultural production by power line structures.

If one assumes that there are seven towers per mile, and that around the base of each tower 1,120 square feet of cultivated land are taken out of production, 9,691 miles of transmission line have resulted in the removal of 1,744 acres from agricultural production. Also, if one assumes that single poles are used to support the remaining 87,136 miles of power line in Alberta, that there are nine poles per mile, and that around the base of each tower 144 square feet of cultivated land are removed from agricultural production, then an additional 2,592 acres of land are removed from the agricultural land base. This 4,336-acre total, however, is a worst-case estimate of the amount of agricultural land removed from production, because not all transmission lines are found in the White and Yellow areas of the province; even in the White and Yellow areas, not all the structures are sited on agricultural land; and depending upon the type of support structure used, there may be as few as an

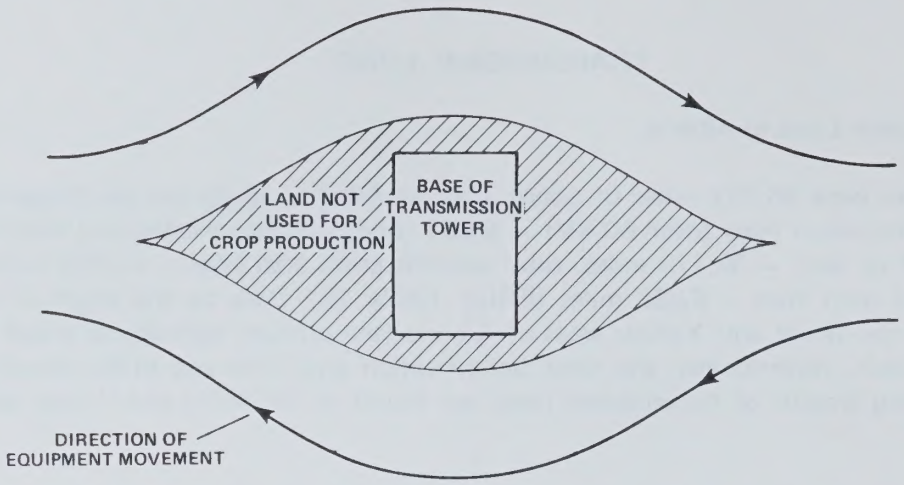

Figure 2. The diamond field pattern around the base of a transmission line tower

Source: Adapted from McKinnon, Allen and Associates (Western) Ltd. 1978a:21

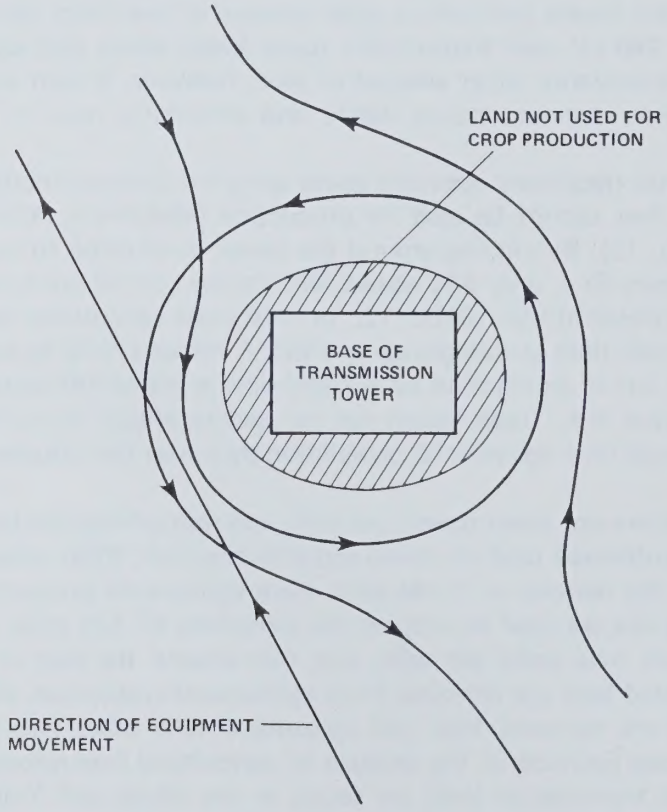

Figure 3. The complex field pattern around the base of a transmission line tower

Source: Adapted from McKinnon, Allen and Associates (Western) Ltd. 1978a:17

average of 4.5 structures per mile. Even the worst-case estimate of 4,336 acres is a small fraction of the total amount of land in Alberta presently affected by linear developments, resource extraction, and industry. After accounting for the qualifications to the 4,336-acre estimate, and by using 1980 statistics, Nieboer (1982: pers. comm.) calculated a more realistic estimate of the land removed from agricultural production by the bases of transmission towers — 624 acres.

Land that cannot be used for production is a cost to farmers. Hanus (1979: 12-13) calculated that the loss of crop production accounted for roughly 20 percent of the extra costs of farming around transmission line structures: 28.1 percent for single poles, 17.2 percent for double poles, and 18.4 percent for steel towers.

The value of extra time needed to farm and the extra cost of weed control around the structures are greater than the value of lost crop production. Hanus (1979: 13) calculated that the extra time for farm operations and the cost of weed control respectively accounted for 50 and 30 percent of the extra costs of farming around power poles. McKinnon, Allen and Associates (Western) Ltd. 1978b: 2) also concluded that the time loss and insurance related to collision of machinery with transmission towers was a major cost to farmers.

In 1977, the average cost of farming around a tower in the middle of a cultivated field was $33.00 to $34.00 (McKinnon, Allen and Associates (Western) Ltd. 1978b: 2). Hanus (1979: 11) estimated the cost of farming around a steel tower to be $31.00; around a double pole, $26.00; and around a single pole, $14.00. When prorated over a larger area, however, the loss from single and double poles is more than 33 percent more than that from steel towers because poles have to be spaced more closely than steel towers (Hanus 1979: 11). The Surface Rights Act (RSA 1980, cS-27 s23(21)) provides for compensation of these costs to the farmer.

The economic impact of power lines on irrigation agriculture is greater than the impact on dryland agriculture. The average extra cost to the irrigation farmer in 1977 was $41.91 per tower (ERCB 1977c: 6-18). The cost varies with the method of irrigation. Gravity irrigation is less severely affected than sprinkler irrigation (Hanus 1979: 10). Side-roll sprinkler systems are usable, but much labor is needed to work around the poles; centre-pivot systems cannot function on fields traversed by power lines. Also, to avoid severe electric shocks the irrigation farmer must take precautions such as ensuring that large nozzles are located at least 50 feet from transmission lines, that the sprinkler systems are well grounded, and that long lengths of pipe do not run parallel and adjacent to transmission lines (Inkis 1977: 4-5). The ERCB (1977c: 6-15), has decided that the potential dangers are not sufficient to refuse right-of-way for a high-voltage transmission line through an irrigation area, but the costs to farmers for taking the necessary precautions should be compensated.

Nuisances and Biological Hazards

Recent objections to the crossing of farmland by transmission tower lines have included: first, nuisances beyond those of greater farming costs and, second, possible adverse biological effects. There are three main types of physical conditions created by very high voltage transmission lines: *corona, electrostatic induction,* and *electromagnetic induction.* These three physical conditions may be annoying or hazardous to those living or working near the lines.

Corona effects include noise emission, radio and television interference, and ozone and nitrogen dioxide generation (Shah 1979: 1; Miller and Kaufman 1978: 8). Noise and radio and television interference are a nuisance only near lines. The production of ozone and nitrogen dioxide could affect the viability of plants and animals, but the production of these compounds is negligible even during bad weather conditions (Shah 1979: 31). The shocks induced by electrostatic and electromagnetic induction are in most cases only annoyances. Even under the worst conditions, electrostatically induced shocks from vehicles under transmission lines are not expected to exceed 5 mA (Miller and Kaufman 1978: 14): a 5 mA shock would be painful, but is about one-half the amount needed to cause a man to lose muscular control and let go of a hand-held conductor. Some measures to minimize electrostatic induction increase the possibility of electromagnetic induction. For example, a grounded system minimizes electrostatic induction, but increases the possibility of electromagnetic induction. With present-day safety standards and caution, the probability of the simultaneous occurrence of situations needed to produce a hazard is low (Wacker 1977: 29; Miller and Kaufman 1978: 8).

Some biological effects may be induced by high-voltage transmission lines. An object placed in an external electric field becomes part of the field (Miller and Kaufman 1978: 8). The internal electric field so generated within a body can cause biological effects by two known mechanisms — bulk tissue heating and membrane excitation (Miller and Kaufman 1978: 9). The evidence for adverse biological effects induced by electrical fields seems inconclusive. Males (1979: 57) noted reduced production by honeybees which may have resulted from the electrical field of a 765 kV transmission line. Subtle effects on the immunology, behavior, and neurophysiology of small animals have been observed after 120-day exposures to electric fields of 100 kV/m, but no effects on the growth, development, metabolic status, fertility, or cardiovascular function were noted (Males 1979: 58). Seedlings of plants with pointed leaves showed only limited damage to the tips of the leaves in electric fields up to 50 kV/m, which is about five times the maximum strength of electric fields beneath the largest transmission lines (Males 1979: 58). Marino and Becker (1978: 8) noted that there is much literature indicating that "a variety of biological organisms, including man, are sensitive to both long- and short-term exposure to ELF [extremely low frequency; i.e., less than 100 hertz] electric and magnetic fields." Miller and Kaufman (1978: 11), however, observed that the results of many such studies are contradictory, and conclude that there is yet no convincing evidence for harmful biological effects resulting from exposure to the electric and magnetic fields of transmission lines (Miller and Kaufman 1978: 33).

Design considerations can mitigate the physical nuisances and potential adverse biological effects of transmission lines. Towers crossing cultivated land can be of sufficient height to minimize electrostatically induced shocks for farmers driving machinery under lines. Existing farm structures can restrict the placement of a transmission line; conversely, the location of houses and barns can be determined by existing high-voltage lines. The construction of high-voltage transmission lines is likely to continue as long as such design solutions are available, and as long as the results of studies on the biological hazards of transmission lines are inconclusive.

Recently formulated Government of Alberta policy on the location of transmission lines has addressed the issues of nuisances and biological hazards. Utility companies must design transmission line routes "to avoid, wherever practical, being located adjacent to residences"

(Alberta Utilities and Telephones 1981: 3). Design in this way must be given consideration similar to that given the cost and reliability of a transmission line. Also, "a committee of independent medical and scientific experts will be established to monitor and report on studies of the biological effects of high-voltage transmission lines, and to assess the need for further studies" (Alberta Utilities and Telephones 1981: 3).

Route Selection and the Impact on Farming

The extra costs of farming near a transmission line are dependent upon the choice of a route for the line. In general, towers situated parallel to the direction of machinery movement result in less loss of production, time, and income than do towers which cross a field diagonally (Scott 1981: 188-189; ERCB 1977c: 6-6). This is partly because a line passing diagonally through a field is longer than one crossing a field parallel to the borders of the field (ERCB 1977c: 6-7). Lines constructed within a field parallel to the border are preferable, however, only if the line is far enough away from the boundary to allow at least one pass of farm machinery (Hanus 1979: 14). More preferable are lines located immediately adjacent to the edge of a field or located away from the field (Hanus 1979: 14; ERCB 1977c: 6-7, 6-8).

Nevertheless, transmission lines which diagonally cross farmland may be advantageous when the diagonal route represents the shortest distance between two locations. Diagonal routes mean greater costs to the individual farmers whose land is crossed, but less cost to the larger farming community. Because of the shorter distances involved, it may even be possible to cross very productive farmland with a diagonal line, and still have less overall impact on farming than a line which crosses less productive land parallel to the borders of the fields. Transmission lines which are constructed in a straight line are also cheaper to build than are lines which change course to avoid productive agricultural land or other obstacles. The cheaper construction costs result from the shorter length of line needed, and from fewer tower structures needed to accommodate direction changes; for example, a tower which accommodates a 90-degree change in the direction of a transmission line is six times more expensive than the towers needed to support a straight line. Cheaper construction costs are economically advantageous to power companies and power consumers.

Route selection involves assessment of the costs of construction, and of the impact on the land base. TransAlta Utilities has devised a numerical technique called Comparative Land Use and Visual Impact Assessment (CLUVIA) to evaluate the impact of different transmission line routes. CLUVIA makes use of an impact scale that accounts for the way a power line would cross property and the type of property that would be traversed. The impact scale was based on a large survey of people served by TransAlta Utilities; 70 percent of the surveys were answered by rural customers and 30 percent by urban customers. By multiplying a unit of length of transmission line by a CLUVIA value, and summing all such values over the length of a route, a numerical assessment of the impact of the route is obtained. There are, however, no firm rules for assessing whether land use impact or construction costs will determine route selection.

The Energy Resources Conservation Board (ERCB) must approve the routes for all lines over 60 kV. The Board has stated that, in general, it prefers boundary rather than diagonal routes on both dry and irrigated land (ERCB 1977c: 6-7, 6-10) and believes that on boundary

routes the line should be placed against the boundary line, rather than a short distance inside it, and that where possible, the line should be on less productive agricultural land (ERCB 1977c: 6-8). In the interests of minimizing the impact on agricultural land, the ERCB will approve a more costly transmission line route, provided it is not too much more costly (ERCB 1977c: 6-7; ERCB 1980c: 7-5). The Board, however, treats each application before it as a unique application, so the criteria governing a decision in one application may not be the same ones governing subsequent decisions.

All future decisions on the location of transmission lines should reflect current Government of Alberta policy. The Alberta Government's policy on the location of major electric transmission lines (normally greater than 138 kV) states that the impact on agriculture must be given consideration similar to that given the cost and reliability of a proposed transmission line. In particular, the policy document states that "transmission line routes will avoid cultivated or irrigated land wherever practical and will, wherever feasible, use existing linear constraints such as road allowances, fence lines, quarter section and section lines" (Alberta Utilities and Telephones 1981: 3). Single-pole transmission lines must, where feasible, locate on road allowances. Except for twinning transmission lines over cultivated land, existing rights-of-way for linear facilities should be used where practical (Alberta Utilities and Telephones 1981: 4). Although the policy attends to matters of power line location, the balance between land use impact and construction costs to be used when selecting a route is not clear. The new policy also appears, in large part, to be an endorsement of knowledge used by industry (for example, TransAlta's CLUVIA system), and criteria used by the ERCB. Implementation of the policy is therefore likely to be successful.

Alternatives

A three-fold increase in power demand is expected between 1980 and 2005 (EUPC 1981: 10). With this level of increase in demand, conflicts between agricultural interests and power generators and consumers are also likely to increase. Are there suitable alternatives which will minimize the adverse impact of power transmission on the agricultural land base?

Some of the alternatives, and their advantages, implications, and feasibility are as follows:

1) Generate power closer to the load centre. This would reduce the total length of transmission line needed, but the resultant impact on the environment would probably be greater than present-day mine-mouth generation. Since the density of power lines is generally greatest near power plants, more transmission lines would be found in close proximity to cities. Moving coal to urban centres for power generation would be more expensive than transporting the electricity. Burning coal near urban centres would expose more people to higher levels of air pollution. Rights-of-way that would have been used for transmission lines may instead be used for new roads or railways to transport the coal, and roads and railways take more land out of production than do transmission lines. Even to have mine-mouth power generation closer to the load centre would reduce the amount of transmission line needed; now, for instance, most of the power used in southern Alberta is generated in central Alberta. Economics do not yet

favor moving mine-mouth generators closer to load centres in southern Alberta (ERCB 1977c: 4-1). The Government of Alberta will consider the feasibility of building power plants closer to load centres (Alberta Utilities and Telephones 1981: 5). The flexibility to generate power closer to load centres is not possible with hydro-electric power sites.

2) Build less reliability into power systems. A certain amount of redundancy is built into power systems to ensure that power outages for customers are kept to a minimum. The transmission network is basically planned so that the loss of power from the major transmission line should not result in a blackout or total network outage. If a less reliable system were acceptable to the public, fewer transmission lines might be built. Greater inconvenience to customers, danger to lives (for example, power outages in very cold weather), and economic loss are some trade-offs for building less reliability into the system.

3) Construct direct current lines. In many respects, direct current (DC) lines are less expensive than alternating current (AC) lines for comparable power loads: "two rather than three lines [conductors] are needed per circuit (for DC, a third less expensive ground return line may be needed); narrower right[s]-of-way and shorter towers can be used" (Keller 1979: 2-111). More DC lines would probably be built were it not for the need to construct converter stations at both ends of the DC line, one to convert the alternating current of the generator to direct current, and the other to reverse the process. The converter stations are very expensive. In 1977, the ERCB (1977c: 5-8) estimated that the cost to construct one small converter station in southern Alberta would be $20 million. Because of the great costs of converter stations, DC lines are not considered economical unless much power (for example, 500-1000 megawatts) is transmitted over several hundred miles (for example, 300 miles) (Keller 1979: 2-111; ERCB 1977c: 5-8).

4) Construct underground transmission lines. Underground transmission lines would avoid the aesthetically displeasing appearance of transmission towers, and may allow even more of the land above the line to be farmed. The environmental costs of underground lines are that they require larger dedicated rights-of-way than do above-ground lines for construction and maintenance, that there is continuous disruption of the ground surface when underground lines are installed (Perry 1979: 2-76), and that stations requiring ground space are needed every 20 miles or so to "bleed off" an electrical charge built up in the ground. Underground transmission lines are very expensive to build; for example, TransAlta Utilities estimated that a double-circuit 240 kV underground line would cost between $1,500,000 and $2,000,000 per mile, while an overhead line would cost $125,000 per mile (ERCB 1977c: 5-7). Underground transmission lines are less technically and economically efficient than overhead lines (Perry 1979: 2-75). There have been no major breakthroughs in superconduction to overcome the technical problems of underground transmission. The Government of Alberta will, however, study the economic and technical

feasibility of installing high-voltage underground transmission lines in urban and rural areas (Alberta Utilities and Telephones 1981: 5).

5) Use transmission towers designed to occupy less land. For newly constructed lines, the use of pedestal towers would have less agricultural impact because they have smaller bases than lattice towers. Because pedestal towers have smaller bases than lattice towers, some reduction in agricultural impact could result by placing pedestal towers in existing rights-of-way off farm fields, with only the conductors overhanging the fields (ERCB 1977c: 5-9). In times past there were some difficulties in purchasing pedestal towers from suppliers, and the cost of a transmission line using pedestal towers is two to three times that of one using double-circuit steel lattice towers (ERCB 1977c: 5-10). In a previous decision, the ERCB (1977c: 5-11) decided that the extra cost of pedestal towers was not justified by the reduction in impact on agricultural land. The Government of Alberta will, however, encourage the use of towers that can accommodate two electrical circuits, even if the second circuit cannot be used immediately (Alberta Utilities and Telephones 1981: 5). Double-circuit towers mitigate the impact of transmission lines on the land base by reducing the right-of-way requirements and the number of transmission towers. Taller transmission towers, and, depending upon the length of time that the second circuit is unused, higher electricity bills in order to pay for the cost of constructing the more expensive double-circuit towers, will be two consequences of the decision to build double-circuit towers now.

6) Build transmission lines on transportation rights-of-way. One reason why the owners of transmission lines have been reluctant to locate lines on transportation rights-of-way was that if the road needed to be widened, relocation of the line was the owner's expense; if the line was on private property, the instigator compensated the owner of the line for relocation (Hanus 1979: 4). Alberta Government policy states that single-pole transmission lines must locate on road allowances where feasible (Alberta Utilities and Telephones 1981: 4); this policy is generally feasible because, first, the cost of relocating single-pole lines is not great compared to higher voltage lines constructed of steel (ERCB 1977c: 5-5) (although it is significant compared to the original installation costs) and, second, there are fewer problems of compatibility of roads with single-pole lines compared to tower lines. In the future, abandoned railway corridors may be used for transmission lines (*Alberta Hansard,* 5 November 1981) if the abandoned corridors provide convenient rights-of-way between generating and load centres.

7) Use higher voltage transmission lines. The cost of a 500 kV line is about three times that of a 240 kV line, and a 500 kV line requires a right-of-way slightly greater than that of a 240 kV line (Hanus 1979: 15); the ERCB (1980c: 4-4), however, decided that a right-of-way for a 500 kV line between the Keephills generating station and the Ellerslie substation should be twice the width of the right-of-way for a 240 kV line in order to provide an extra margin of safety. A 500 kV line is, however, capable of carrying four times the power of a 240 kV

line (Inkis 1977: 2). Using high-voltage lines would greatly reduce the number of rights-of-way crossing agricultural land, and would, therefore, reduce the impact on the agricultural land base. These high-voltage lines will be increasingly common in Alberta beyond the mid-1980s (Hanus 1979: 15; Nieboer 1980: 5; ERCB 1980c: 3-5). Security of power supply, and nuisance and biological effects are concerns related to these, and higher voltage transmission lines.

Few of these alternatives presently show much promise for use in programs to conserve land for agriculture, unless the consumer is willing to pay a much higher price for electricity. Since most of the related land use problems in the future will originate from a substantial increase in provincial demand for power, reductions in total and per capita demands for power could be the most important alternative in efforts to conserve agricultural land. Since commercial and industrial users are expected to account for 76.1 percent of the expected increase in power demand in the time period 1986 to 2006 (McKinnon, Allen and Associates (Western) Ltd. 1978a: 2), energy conservation programs in the workplace could be a very important component in efforts to reduce power demands.

ROADS

Impact on the Land Base

Roads affect agriculture in many subtle ways. Some of these are environmental in nature. For example, when an elevated roadbed crosses hills parallel to the crest, air drainage is impaired; this increases the probability of frost damage to crops upslope of the road (Schmidt Jr. 1980: 597). Soils near major roads may be polluted by oils and greases, and by lead from herbicides used to control roadside vegetation and from automobile exhausts (DeLeuw Cather Consulting Engineers and Planners 1974: 28). Roads provide infrastructure for housing and urban developments which may consume agricultural land, and tend to encourage further developments alongside them. Other effects are nuisances. Improved road access near farms may increase the incidence of trespass for recreation and vandalism. Such impacts may make farming a more difficult and less desirable occupation. The construction of roads, however, more significantly affects the agricultural land base by fragmenting agricultural parcels and by consuming agricultural land. Against these negative effects is the essential function of roads for providing access to markets, and for providing supplies and services to farms.

Farms were originally plotted out on the grid system with most of the roads following boundary lines between the farms. When new highways are constructed between urban centres, using the shortest route is desirable in order to minimize construction costs and travelling time. This often means that a highway crosses a farm diagonally, changing the number, size, and shape of fields.

Fields that are reduced in size are more expensive to farm because of, first, the extra time needed to move equipment to the parcels of land created by the road and time consumed by more turns of the equipment in small fields and, second, increased fuel consumption and wear resulting from extra usage of the farm equipment (Schmidt Jr. 1980: 594). The corners of triangular fields created by diagonal crossings are lost from production because farm machinery cannot be turned tightly enough in them. In California, one land appraiser

estimated that the operating costs of farming a triangular field with row lengths less than one-quarter of a mile were increased by about 25 percent (Schmidt Jr. 1980: 595). Irrigation of triangular fields is difficult and costly, since uniform distribution of water on the fields is often impossible (Schmidt Jr. 1980: 596). The construction of major highways on the rights-of-way of existing quarter lines would reduce fragmentation of farm fields.

The construction of freeways and expressways on existing rights-of-way, however, may not preclude the fragmentation of farms. Access to freeways usually occurs at two- or four-mile spacings. Farmers with property on both sides of the freeway must travel along service roads which parallel the freeway in order to cross it. For the farmer this results in extra "time, money, and inconvenience to shuttle farm machinery, equipment, and livestock back and forth, to inspect crop and field conditions" (Schmidt Jr. 1980: 590). Furthermore, freeways built in existing rights-of-way may consume as much land as freeways which are built across fields (Schmidt Jr. 1980: 590). The service roads alongside freeways built on existing quarter lines, combined with widening of the right-of-way, consume about the same amount of land as freeways newly built across a field; service roads are not usually found alongside freeways which cross a field diagonally because a farmer can access the freeway using the quarter-line roads which intersect the freeway.

To date in Alberta, the removal of land from agricultural use for road construction has probably been more significant than the effects described above. There are about 92,650 miles of roads and highways in Alberta which occupy nearly 870,000 acres of land (data from Alberta Transportation). These figures do not include local roads on the rural land access system which are not open to the public, or urban roads. Eighty-four interchanges occupy another 1,865 acres. A complete set of data on the quality of land used for the roads is not available.

What is available is data on land used for road and highway construction in the White and Yellow areas of Alberta from 1976 to the end of 1980. This data, and some of the data found in subsequent sections of the report, was obtained from Alberta Agriculture. A description of the data collection and analysis methodologies can be found in *An Inventory of Changes in Alberta's Agricultural Land Base Between 1976 and 1980* (Birch 1982: 4-27). The total number of acres used for various road construction activities in this five-year period were:

New Roads	7,063
Road Widening	13,162
New Highways	2,606
Highway Widening	808
Public Works	1,438
Total	25,077

The main distinction between the categories is that "roads" are funded by the Alberta Government and municipalities but are administered by the municipalities, and "highways" are funded and administered by the Alberta Government. The category "public works" includes rest stops, equipment yards, some roadside gravel pits, and so on, not within urban areas. Road-building activity by the municipalities accounts for over 80 percent of that

occurring within the White and Yellow areas of the province. More land is used for road widening than for all other types of construction combined. The extent of the impact can be appreciated when the acreage used by each of the construction activities is examined in turn.

In nine administrative units, more than 200 acres were used for new road construction, which accounted for 45.3 percent of the total new road-building activity in Alberta. Table 1 shows the acreage used in these nine areas. Except for the County of Parkland, the areas of major new road construction were outside the Edmonton-Calgary corridor (Figure 4); in fact, 82.2 percent of all the land used for new road construction in Alberta was outside the corridor. About 18.2 percent (weighted average) of land used within these nine high-activity areas was class 1-3* land. The percent of class 1-3/class 1-6 land used was calculated to indicate the amount of better land relative to poorer land that was consumed by new roads. The percentages for land consumed by road construction were then compared with percentages of class 1-3/class 1-6 within the White and Yellow areas of the administrative unit, to determine if attempts to avoid the use of high-quality land were apparent. The highest class 1-3/class 1-6 ratio for road construction, 39.3 percent, occurred in M.D. Provost and only in two areas, Special Area 4 and I.D. 15, were the ratios for road construction equal to or greater than the class 1-3/class 1-6 ratios for all land within the administrative units. The use of high-quality agricultural land in areas of major new road construction does not appear alarming. But some high proportions of good agricultural land are used for new road construction where construction activity is not so pronounced. Table 2 shows six areas where the class 1-3/class 1-6 percentages for new road construction were higher than the percentages for the administrative units as a whole, and where at least 100 acres were used for new roads. Although it is possible that the better land was unavoidable if the roads were to be constructed, the high ratios suggest that there has not been a concerted effort to avoid high-capability agricultural land in these six areas.

The ten administrative areas which used the greatest amounts of land for road widening, and the acreages involved, are shown in Table 3. Four of the ten areas, the counties of Parkland, Mountain View, Lacombe, and Leduc, are within the Edmonton-Calgary corridor. The use of high-capability agricultural land in the ten high-activity areas shown in Table 3 is high; 43.1 percent (weighted average) of the land used for road widening was class 1-3 land. The percentage of class 1-3/class 1-6 land used for road widening was higher than the percentage for the administrative area as a whole in seven of the ten areas. The rate of consumption of high-capability land, compared to availability, was notably high for Special Area 2, I.D. 1, and M.D. Wainwright. In the high-activity areas, more class 1-3 land is generally used for road widening than for new road construction. The use of more class 1-3 agricultural land for road widening might be expected. First, road widening occurs in better established areas; that is, those likely to contain better soils, whereas new roads are built in

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*The Canada Land Inventory (CLI) system of land classification for agriculture is widely used to indicate the value of land for farming. Of the seven classes, classes 1 to 3 are considered good agricultural land, classes 4 to 6 are considered to have some value for agriculture, and class 7 has no agricultural value.

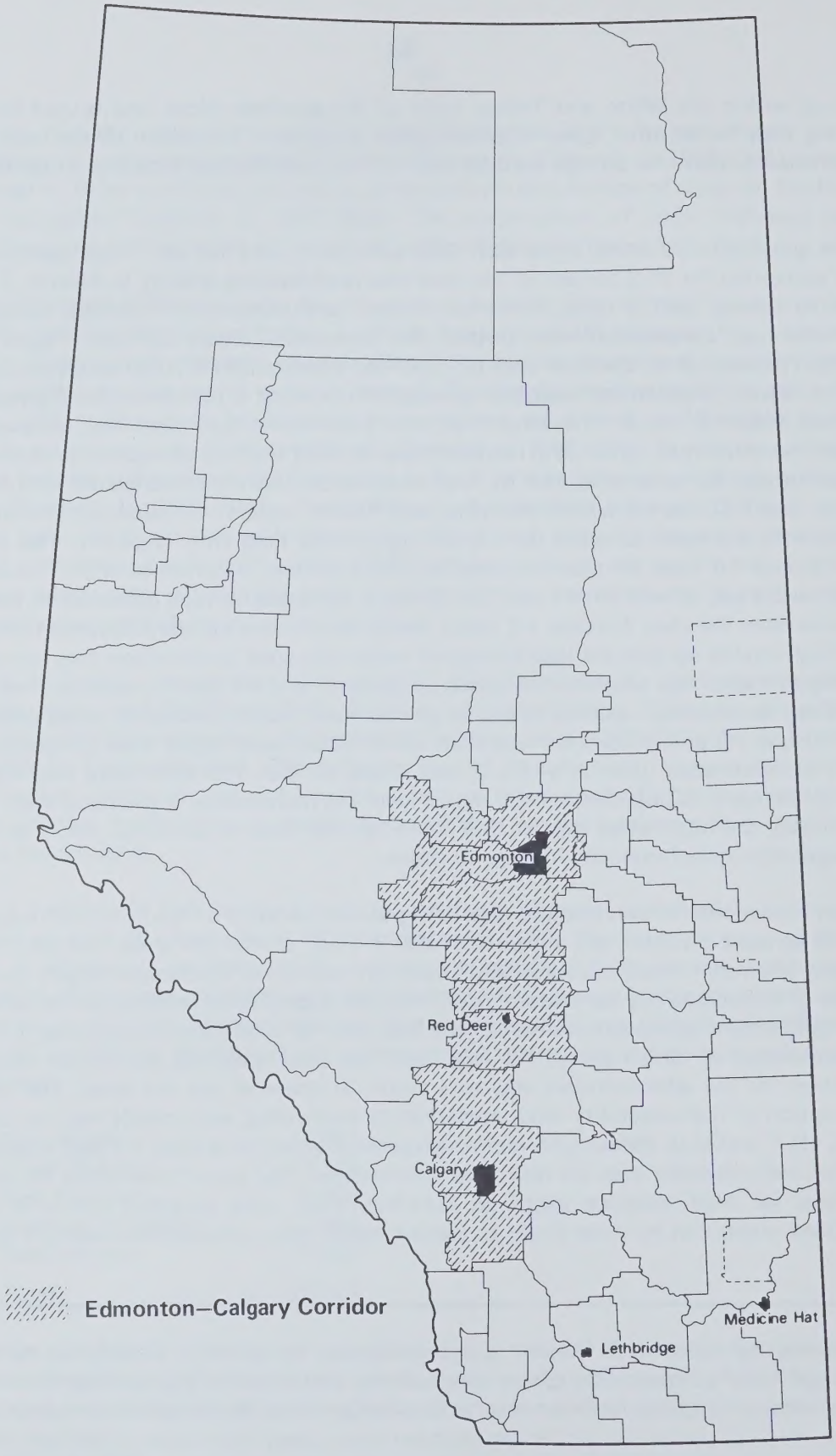

Figure 4. The Edmonton-Calgary corridor

Table 1. Acreage of land used for new road construction in nine high-activity areas of Alberta from 1976 to 1980

Administrative Unit	Acreage of All Land Classes	Acres of Class 1-3 Land	Percent Class 1-3/ Class 1-6 Land Used for New Roads	Percent Class 1-3/ Class 1-6 Land in the Administrative Unit*
I.D. 18	619	12	2.2	2.6
Special Area 4	436	138	31.7	19.2
Co. Parkland	375	112	34.4	46.7
Co. Athabasca	366	28	9.0	27.7
Co. St. Paul	336	87	25.9	40.3
I.D. 14	334	24	9.1	14.4
I.D. 15	300	40	14.5	14.5
M.D. Provost	225	88	39.3	42.6
I.D. 17	208	53	34.4	53.2
TOTAL	3199	582		

*White and Yellow Areas only

Table 2. Comparison of new road construction and administrative unit Class 1-3/Class 1-6 percentages for six low-activity areas of Alberta from 1976 to 1980

Administrative Unit	Percent Class 1-3/ Class 1-6 Land Used for New Roads	Percent Class 1-3/ Class 1-6 Land in the Administrative Unit*
M.D. Westlock	95.2	61.8
M.D. Taber	76.5	25.8
M.D. Rocky View	71.7	64.0
I.D. 22	70.0	53.8
M.D. Wainwright	60.9	45.8
M.D. Pincher Creek	51.5	44.1

*White and Yellow Areas only

agricultural fringe areas where poorer soils are more likely to be encountered. Second, in times past, avoidance of better agricultural soils was not a major concern during the construction of new roads, and, in many cases, was simply unavoidable. If such roads are built today, avoidance of high-quality agricultural soils is a desirable objective.

Only 10.4 percent of all such construction in Alberta from 1976 to 1980 was for new highways. Most of the new highway construction (69.2 percent) occurred outside the Edmonton-Calgary corridor. There were eight administrative areas in which more than 100

Table 3. Acreage of land used for road widening in ten high-activity areas of Alberta from 1976 to 1980

Administrative Unit	Acreage of All Land Classes	Acres of Class 1-3 Land	Percent Class 1-3/ Class 1-6 Land Used for Road Widening	Percent Class 1-3/ Class 1-6 Land in the Administrative Unit*
Special Area 2	1100	129	11.8	3.9
I.D. 1	963	150	17.1	8.1
Co. Vermilion	710	502	71.6	67.1
Co. Parkland	665	365	57.6	46.7
Co. Mountain View	458	337	73.6	65.3
M.D. Wainwright	453	332	73.5	45.8
Co. Lacombe	421	330	78.4	67.0
Co. St. Paul	420	140	33.9	40.3
Co. Athabasca	410	83	24.4	27.7
Leduc	384	210	60.0	65.5
TOTAL	5984	2578		

*White and Yellow Areas only

Table 4. Acreage of land used for new highways in eight high-activity areas of Alberta from 1976 to 1980

Administrative Unit	Acreage of All Land Classes	Acres of Class 1-3 Land	Percent Class 1-3/ Class 1-6 Land Used for New Highways	Percent Class 1-3/ Class 1-6 Land in the Administrative Unit*
I.D. 14	579	0	0.0	14.4
I.D. 1	426	335	79.2	8.1
Co. Strathcona	286	146	51.2	62.0
I.D. 21	243	6	2.6	48.3
Special Area 4	189	114	60.3	19.2
I.D. 17	145	9	9.6	53.2
Co. Leduc	122	76	62.3	65.5
Co. Wetaskiwin	111	105	94.6	56.9
TOTAL	2101	791		

*White and Yellow Areas only

acres of land were used for new highways (Table 4). The eight areas identified in Table 4 accounted for 80.6 percent of new highway construction between 1976 and 1980. Within the eight administrative units, 37.6 percent (weighted average) of the land converted was class 1-3. Three areas, I.D. 1, Special Area 4, and the County of Wetaskiwin, showed class 1-3/class 1-6 percentages for new highways higher than the class 1-3/class 1-6 percentages for the administrative area as a whole. Some very high rates of class 1-3 land usage occurred in areas not

identified in Table 4. For example, although only 66 acres in the County of Mountain View were used for the construction of new highways, only class 1 soil was used. For the most part, however, rates of use of high-capability agricultural land for the construction of new highways were not inordinately high.

The least amount of land used for road construction in Alberta between 1976 and 1981 was for highway widening. Table 5 provides data on seven administrative units in which 60 or more acres were used for highway widening. The eight administrative units accounted for 79.7 percent of the land used for road widening. Of the seven administrative areas recording the highest land usage for highway widening, only two — the counties of Parkland and Strathcona — were within the Edmonton-Calgary corridor. In both these counties, the class 1-3/class 1-6 percentages of land used for highway widening were greater than the class 1-3/class 1-6 percentages for the whole administrative unit. The same was true of I.D. 1. Within the four other areas of highest land usage, the use of high-capability land was restrained. Within the seven high-activity areas for highway widening, 32.3 percent (weighted average) of the land used was class 1-3 land; the provincial (weighted) average was 34.7 percent. Although only two counties found in Table 5 are located in the Edmonton-Calgary corridor, most of the use of high-capability agricultural soils for highway widening occurred in the corridor; exactly 70 percent of the class 1-3 soils used for highway widening were used in the corridor.

There were eight administrative areas in which 75 acres or more were used for public works projects (Table 6). These eight administrative areas accounted for 61.8 percent of the land used in Alberta for public works projects. Unusually large amounts of good-quality land were used for public works. Five of the eight areas had class 1-3/class 1-6 percentages of land used for public works greater than the class 1-3/class 1-6 percentages for land within the whole administrative unit. In some areas, only high-quality agricultural soil was used. In the County of Lac Ste. Anne, only class 2 and 3 land was used. In the County of Forty Mile,

Table 5. Acreage of land used for highway widening in seven high-activity areas of Alberta from 1976 to 1980

Administrative Unit	Acreage of All Land Classes	Acres of CLI 1-3 Land	Percent CLI 1-3/ CLI 1-6 Land Used for Highway Widening	Percent CLI 1-3/ CLI 1-6 Land in the Administrative Unit*
Co. Beaver	155	21	13.5	71.9
Co. Parkland	142	84	58.5	46.7
I.D. 1	89	34	38.6	8.1
Co. Strathcona	72	58	80.6	62.0
Co. Camrose	65	11	16.9	83.3
Co. Forty Mile	62	0	0.0	24.1
Special Area 2	60	0	0.0	3.9
TOTAL	645	208		

*White and Yellow areas only

Table 6. Acreage of land used for public works in eight high-activity areas of Alberta from 1976 to 1980

Administrative Unit	Acreage of All Land Classes	Acres of CLI 1-3 Land	Percent CLI 1-3/ CLI 1-6 Land Used for Public Works	Percent CLI 1-3/ CLI 1-6 Land in the Administrative Unit *
M.D. Starland	164	97	59.1	61.9
M.D. Pincher Creek	157	0	0.0	44.1
Co. Warner	119	89	74.8	59.2
M.D. Cardston	110	110	100.0	51.2
Co. Lac Ste. Anne	100	100	100.0	49.9
M.D. Smoky River	85	85	100.0	81.7
Co. Forty Mile	78	78	100.0	24.1
Co. Beaver	75	0	0.0	71.9
TOTAL	888	559		

*White and Yellow areas only

and in the municipal districts of Smoky River and Cardston, only class 2 land was used. The placement of public works near highways appears to be without general regard for impact on the agricultural land base. About three-quarters of the land used for public works was outside the Edmonton-Calgary corridor.

Planning and the Use of Agricultural Land

The development of a transportation network has had a substantial direct impact on the land base. Alberta Transportation is integrally involved in the planning and construction of primary and secondary highways in the province. The Department's activities do not indicate a major attempt to avoid the use of agricultural land, probably because protection of agricultural land is not a mandate of the Department of Transportation.

Conservation of agricultural land may, however, incidentally result from Alberta Transportation's activities. For example, the Department tries to avoid fragmentation of agricultural lands when it constructs new roads. This is more an attempt to avoid servicing costs to possible future subdivisions within the fragmented parcel, than it is an attempt to conserve farmland. Also, where there are mutually exclusive alternatives for road construction, a rough benefit/cost analysis is done. The money that a farmer loses from his annual income, which is a function of the quality and quantity of land lost, is calculated as one of the costs of a project; a decision for construction based on benefit/cost analysis would, however, likely be made on grounds other than costs due to loss of agricultural production. For example, decisions to widen roads essentially preclude choices for preserving the best agricultural soils because the quality of land is usually the same on both sides of the road.

Alberta Transportation, as administrator of the Public Highways Development Act, does have some input into developments which could affect agricultural lands within a maximum of 1,000 feet from a highway (Public Highways Development Act, RSA 1980, cP-28 s26(2)).

All developments within this distance of a highway must receive a permit from Alberta Transportation. A permit can only be refused, however, if it does not meet the standards defined in sections 23 to 26 of the Subdivision Regulation under the Planning Act. The Department does not regulate the type of land use at the side of the road; the use is regulated by the area structure plans of the municipalities, into which Alberta Transportation may have some input. For instance, Alberta Transportation does try to organize industrial growth by urging municipalities to organize their industries into parks. This may result in less conversion of agricultural land to industrial use, but the impetus for this action is, once again, sound transportation planning rather than conservation of agricultural land.

As long as the role of Alberta Transportation is primarily one of accommodating demands for roads, a decrease in construction will result only from reduced user demand for roads. There are few alternatives available. To conserve farmland a reduction in road widths is possible, but not very feasible because, first, people's expectations for quick traffic flow are high and to meet these expectations extra land for passing lanes is needed and, second, increases in the cost of fuel which have led to a decrease in the size of North American automobiles have resulted in an increase in the size of tractor-trailer units, and extra land is needed to accommodate the large tractor-trailer units. Alternate transportation modes are not likely. The low population density, even within the corridor area, ensures that the automobile will be the main transportation mode unless there is a government supported, common-carrier service (Mayne and Morrall 1979: 219). For example, even before a light rail extension from St. Albert to Edmonton would be warranted, St. Albert's population would have to approach 175,000 (ERPC 1976: 5), about five to six times the present-day population. Reducing user demand for roads is beyond Alberta Transportation's capabilities. Reducing demand is the responsibility of society as a whole. For example, congestion on principal highways within the Edmonton-Calgary corridor results primarily from commuter trips and recreational intercentre trips (Mayne and Morral 1979: 211). With a government policy of decentralization, and with so many urban dwellers seeking weekend recreation outside the city, the consumption of agricultural land for roads must inevitably result. A decision to reduce the amount of land used for roads requires complementary land use and life style decisions.

PIPELINES

Length of Pipeline in Alberta

Pipelines are used to move hydrocarbons and other substances from wells to gathering points and then to processing plants, and from processing plants to consumers. There are approximately 110,800 miles of pipeline in Alberta which are under the jurisdiction of the ERCB. Table 7 shows the length of pipeline by function. The lengths of pipeline related to soil quality classes are not documented by the ERCB, the source of data for Table 7. Another 1,200 miles of pipeline which move, or will be moving hydrocarbons out of the province are under the jurisdiction of the National Energy Board and the Northern Pipeline Agency. The total length of pipeline in Alberta is therefore approximately 112,000 miles.

Table 7. Length of pipeline by function in Alberta, July 1981

Type of Pipeline	Length of Pipeline (miles)
Main oil lines	7,649
Secondary (gathering) oil lines	5,290
Main gas lines	13,397
Secondary gas lines	23,913
Secondary lines for fresh or salt water and other substances	7,005
Distribution lines (small diameter gas lines in gas co-operatives)	43,400
Flow lines from wells to a battery site	10,164
TOTAL	110,818

Impact on the Land Base

Land is disturbed when pipelines are installed, but the resultant harm to the land base seems to be minimal. Toogood (1974: 15) observed no decrease in crop yield over pipelines in a Black soil near Edmonton. In some cases, there was a significant improvement in yield. The increases in yield may have resulted from improvements in soil tilth after installation of the pipeline, and from bringing mineral nutrients up from the subsoil during trenching (Toogood 1974: 15). A decrease in soil fertility was noted only in solonetzic soils (Toogood 1974: 16). The decrease probably resulted from bringing large amounts of subsoil high in sodium to the surface. DeJong (1979: 39-40), however, observed that the installation of pipelines improved the productivity of solonetzic soils. He offered two hypotheses for the improvement: first, trenching brought available nutrients from the subsoil to the soil surface; second, water movement was enhanced due to break-up of the "hardpan" subsoil.

Different types of solonetzic soils may account for the contradictory results. Like Toogood, deJong (1979: 39) observed that the installation of pipelines had no long-term effects on the productivity of chernozemic soils.

In some cases, the warmth of the liquids passing through a pipeline may create problems for farmers. The warmth, once transferred to the soil, hastens the maturation of crops growing above the pipeline. A mature crop over the pipeline, coincident with an immature one in the rest of the field, complicates the timing of the crop harvest.

The type and degree of disturbance may also depend upon whether the pipeline is crossing cultivated land or rangeland. On productive cultivated land, the temporary disturbance of somewhat greater amounts of land may be acceptable in order to minimize productivity losses. The losses can be minimized by removing the topsoil before the trench is dug, and replacing it again after the pipe is laid down. The trend on rangeland is to disturb as little land as possible. Topsoil handling is therefore not common on rangeland, and some reduction in productivity over the pipeline may result from mixing soil layers. Most farmers' complaints about pipeline installation deal not with reduced crop yields, but rather with poor filling of trenches and inadequate clean-up of stones and debris (deJong 1979: 41).

There is probably more reason to be concerned with the effects of pipeline spills on soil productivity than with the effects of pipeline installation. Although most spills affect less than 1.2 acres of land (deJong 1980: 76), and although the total farm acreage affected each year by pipeline spills is only about 300 acres (deJong 1979: 40; ERCB 1980a: 21), the impact on the affected soil may be great. Reductions in yield caused by oil spills are due to:

1) Toxic Effects. Usually the toxic effects of spilled oil are minimal. The most toxic components of oil are the volatile aromatics, which are rapidly lost from exposed oily surfaces (Rowell 1977: 158). Nyborg et al. (1974: 148) observed few toxicity symptoms in plants growing on oil-treated soils. Toxic effects, however, may result from anaerobic conditions within the soil caused by an oil spill.

2) Poor Wettability and Aeration. It is difficult for water to infiltrate through soils coated with oil. Instead, water tends to collect on the soil surface, or if water does infiltrate into the soil, the soil may subsequently dry out slowly (deJong 1979: 42). Very wet and anaerobic conditions so created may result in the formation of hydrogen sulphide, ferrous and manganous ions, and organic substances (Rowell 1977: 154) which are toxic to plants. Even without the production of toxic substances, the roots of plants will not survive under conditions of waterlogging. Nyborg et al. (1974: 149) considered waterlogging to be a major reason for the lack of revegetation after an oil spill.

3) Nutritional Effects Caused by Oil Breakdown. Oil can be decomposed by soil micro-organisms which use the oil as a source of carbon and energy. These organisms also use soil nutrients which would otherwise be available for crop use. Consumption of nutrients by high populations of decomposer micro-organisms is thought to be a major reason for the lack of revegetation after an oil spill (Nyborg et al. 1974: 149; Toogood and McGill 1977: 17).

Fortunately, reclamation of soils contaminated by oil spills is often feasible. One of the best ways to reclaim soils contaminated by oil spills is to add nutrients to the soil in order to speed up the decomposition process. Addition of nutrients to the soil, for example, has increased the respiration rate of decomposer micro-organisms five- to ten-fold (McGill et al. 1974: 119). Rowell (1977: 160) suggested that to maintain maximum growth rates of micro-organisms, fertilizers containing the nutrients nitrogen, phosphorus, potassium, and sulphur should be added to the soil; the nutrients in shortest supply, though, tend to be nitrogen and phosphorus (McGill et. al. 1974: 120). More than 1000 pounds of nitrogen per acre may be required for reclamation, but it should be applied in several applications in order to avoid losses of nitrogen by runoff, leaching, and denitrification and to avoid salt problems (Rowell 1977: 160). The amount of fertilizer required depends upon local conditions, including the type of oil spilled; "readily decomposable paraffinic crudes require more fertilizer than heavy asphaltic crude" (deJong 1979: 43). Fertilizer applications must be accompanied by cultivation of the soil in order to incorporate the fertilizer to establish a good pore structure (Rowell 1977: 153, 160; deJong 1979: 43). Excess tillage, however, can cause breakdown of soil structure and can render the soil susceptible to wind erosion (deJong 1979: 43).

Treatment of oil-contaminated soil with fertilizers and cultivation may result in quick reclamation. Field experiments have shown that soils with light applications of oil (20 gallons or less per 150 square feet) can be reclaimed within a year; soils with heavy applications of oil (90 gallons or more per 150 square feet) require five or more years for reclamation (Toogood and McGill 1977: 11). The length of time required for reclamation will depend on the crop to be grown subsequently on the soil. The reclamation needed to grow oats, for example, would take less time than the reclamation needed to grow rapeseed, because oats are more tolerant of oil than is rapeseed.

Unfortunately, the reclamation of soils contaminated by oil spills is not as straightforward, nor as successful, as the previous paragraphs imply. Two examples of complications are:

1) Much of the oil is spilled in the subsoil. Reclaiming contaminated subsoils is much more difficult than reclaiming topsoils. Sometimes oil spilled underground may be brought to the soil surface by raising the water table (deJong 1980: 81), and once the oil is at the soil surface it can be removed by the methods previously described.

2) Spills are often a combination of oil and brine. The difficulties of reclaiming brine-affected soils are similar to those of reclaiming saline mine spoils, described on pages 40 and 41 of this report. Brine-affected soils are, however, more treatable than are saline spoils because the generally small size of brine-affected areas makes them more amenable to treatment. Weighing against the treatability of brine-affected soils is the greater damage to soils caused by salt water compared to oil. The greater damage results because more salt water than oil is spilled in Alberta, brine recovery is less efficient than is oil recovery, and salts are not biodegradable (deJong 1980: 81). On well-drained or slightly saline sites, reclamation involves the application of calcium or organic amendments to the soil; on poorly drained areas, drainage is probably also necessary (deJong 1980: 81-83). A combination of oil and brine is much more difficult to reclaim than oil or brine separately (deJong 1979: 39).

The success of some of the experiments on reclamation described in the previous paragraphs may be due to the use of oil from which impurities such as salt and hydrogen sulphide had been removed (Toogood 1974: 104). Further reservations about the success of oil spill reclamation stem from the lack of assessment of subsequent crop quality in reclaimed areas (Toogood and McGill 1977: 25).

There are some requirements in place to reduce the impact of oil spills on farming. The ERCB ensures that all oil well and pipeline operators have satisfactory spill contingency plans. All the oil well and pipeline operators in Alberta have formed 21 co-operatives to clean up oil spills anywhere within the province. Even with these measures, after the initial clean-up has been completed, a farmer will have ongoing costs related to reclamation, such as repeated soil samplings and soil analyses, and loss of revenue from the spill site due to reduced crop production or crop quality between clean-up and full reclamation (Toogood and McGill 1977: 41). The Surface Rights Board can have compensation paid to a farmer for such losses to personal property provided the losses are brought before the Board within

six months of the last date of occurrence of damage, and provided the amount of compensation claimed does not exceed $2000 (Surface Rights Act, RSA 1980, cS-27 s38(2)).

UTILITY CORRIDORS

If anticipated increases in demands for products and services in Alberta are to be met, more rights-of-way will be needed to convey commodities to their destinations. Continued reliance on single-use corridors will result in the needless duplication of problems for agriculture. Multiple-use corridors could obviate some of the land use problems associated with single-use corridors. Multiple-use corridors, however, have not been widely adopted, probably because they are not clearly advantageous to farmers, the facility owners, or to society.

One advantage of accommodating several linear facilities in one corridor is that less land is used for rights-of-way than is the case when several single-use corridors are constructed (Ontario Ministry of Transport and Communications 1978: 3). Also, one corridor accommodating several linear facilities would result in the fragmentation of fewer parcels of land than would several single-use corridors (Hanus 1980a: 6). From a land use perspective, the main disadvantage of multiple-use corridors is that agricultural operations within the corridor are more severely disrupted than are operations in a single-use corridor (Hanus 1980a: 8). The greater disruption can be partially due to a reduction in the flexibility to select a route which avoids agricultural land.

Once multiple-use corridors are designated, approvals for and acquisitions of rights-of-way would probably be quick (Hanus 1980a: 6; Ontario Ministry of Transport and Communications 1978: 4-5). But for the facility owners there are many disadvantages, such as:

1) The company may not have undisputed control over a right-of-way in a corridor.

2) Companies may have to spend more time planning their activities because of additional constraints. One such constraint is technical compatibility of linear facilities in the corridor; except in the case of transmission lines, which can induce electric charges in parallel metallic facilities, engineering know-how can overcome problems of technical compatibility (Nieboer 1980: 6).

3) Greater costs. Regardless of where a multiple-use corridor is built, facilities within the corridor will probably have origins or destinations outside of the corridor (Nieboer 1980: 8). The total length of the facility would then be greater than the shortest distance route, which means greater construction, operation, and maintenance costs for the company (Hanus 1980a: 7). The greater costs would be passed on to the users of goods and services moved through the corridor.

The cost to society for acquiring multiple-use corridors is considered to be less than the cost for acquiring many single-use corridors (Hanus 1980a: 7). One of the larger risks to society, though, is a decrease in security of supply of goods and services moved through the corridor. Since many utilities are located in a multiple-use corridor, serious disruptions in supply could result from vandalism, storms, and floods (RDRPC 1978: 23).

A second reason why multiple-use corridors have not been widely adopted in Alberta is that questions about time, location, and demand of future activities to be served by the corridors cannot be answered with enough certainty to designate a network of corridors throughout the province (Homeniuk 1980: 8; Nieboer 1980: 7). Enough is known, however, about the future direction of growth near the cities of Calgary and Edmonton. There, Restricted Development Areas (RDAs) have been designated as multiple-use corridors. Calgary's RDA is five miles wide. Within it, a one-half mile wide transportation and utility corridor is protected, and all other developments within the RDA must be approved by the Land Assembly Division of Alberta Environment. Edmonton's RDA is a one-half mile wide transportation and utility corridor only. Routes for a major transportation and utility corridor between Fort McMurray and the Edmonton area have been recommended to the Government of Alberta by Stewart, Weir, Stewart, Watson, and Heinrichs (Consultants) (1974). Waiting until there are complete answers to questions about time, location, and demand of future activities to be served by corridors, however, seems to negate the use of corridors as a planning tool to shape overall land use patterns (RDRPC 1978: 23).

The Energy Resources Conservation Board is in a position to advise the Government of Alberta on matters relating to the transportation and transmission of energy resources and energy (Energy Resources Conservation Act, RSA 1980, cE-11 s21(1)) and therefore on utility corridors. The ERCB feels that a network of utility corridors throughout the province would not be appropriate now because future growth patterns in Alberta are unknown (ERCB 1980c: 8-1). Although the Board does endorse the concept of utility corridors where there are well-defined needs for utility services between two areas (ERCB 1980c: 5-1, 8-1), concerns about reliability of supply prevented the establishment of an electric power corridor for two 500 kV lines from the Keephills generating station to Ellerslie, even when the requisite conditions were met (ERCB 1980c: 5-2). Because of the Board's concern about reliability of supply, the ERCB (1980c: 5-3) has also expressed misgivings about the use of the RDA bordering Edmonton for more than one 500 kV power line right-of-way. Concerns about reliability of supply arise when most of the supply needed by a larger load centre is found within one corridor. When the ERCB feels that it can define multiple-use corridors that will accommodate a significant number of utilities, multiple-use corridors serving as conduits for energy resources are likely to be more common in Alberta.

Whenever the multiple-use corridors are built, however, there will be an attempt to minimize the impact of the corridor on the agricultural land base. Current Alberta Government policy states that "whenever *possible,* priority for multiple-facility corridor locations will be given on public lands that have a low potential for agricultural productivity and other renewable resources" (Alberta Utilities and Telephones 1981: 5; emphasis in original).

THE IMPACT OF RESOURCE EXTRACTION ON ALBERTA'S AGRICULTURAL LAND BASE

COAL MINING

Impact on the Land Base

One of Alberta's great natural resources is coal. There are an estimated 89.1 billion tons (81 billion tonnes) of potentially recoverable coal in Alberta (ERCB 1980d: X). Slightly more than 90 percent of the potentially recoverable coal is found in the Plains region; that is, in that area of the province extending southward from Lesser Slave Lake and eastward from the foothills of the Rocky Mountains (Figure 5).

Much of the coal underlies Plains soils suitable for agriculture. Agriculture is the prime use for at least 47 percent of the total coal field acreage in Alberta (Goettel 1977: 98). Nearly 3.1 million acres of land in Alberta are underlain by coal fields and isolated deposits; 1.3 million acres of this total are arable (class 1-4) soils, and 211,900 acres are suitable for improved pasture (class 5) (Goettel 1977: 98-100). Underlying the 1.5 million acres of class 1-5 land is coal that is mineable by both underground and surface methods. Since the coal of the Plains region will be the main resource used to generate the three-fold increase in electricity over the next 25 years (EUPC 1981), some agriculture/coal industry conflicts are inevitable.

Conflicts are inevitable because most of the Plains coal mined over the next 25 years will be strip mined, and that type of mining takes lands out of agricultural production for some years. About 8.2 billion tons of coal (10.3 percent of the ultimately recoverable coal in the Plains region) can feasibly be recovered by strip mining (ERCB 1980d: 9-2). Potentially, 384,000 acres (600 square miles) of largely agricultural land in Alberta could be affected by strip mining (Techman Ltd. 1977: iv). Although there is less coal available for strip mining than there is for underground mining, and although strip mining disturbs more land than underground mining, strip mining is likely to be the predominant form of mining over the next 25 years mainly because of cost advantage. For example, in 1978, surface mineable sub-bituminous coal was about five dollars a ton cheaper to recover than was underground coal (Stanley Associated Engineering Ltd. 1978: 1.5). The cost advantage, in part, results because of better coal recovery in strip mines. The ERCB (1980d: 5-4) estimated that about 85 percent of the coal within a seam could be recovered by strip mining, whereas about 50 percent of the coal within a seam could be recovered by underground mining.

To date, only a small fraction of the 384,000 potential acres have been disturbed by coal mining. Existing and already approved coal leases will affect 30,080 acres of land (Harrington 1982: pers. comm.). As of mid-1981, over 99 percent of the coal used for thermal power production in Alberta was obtained from five surface mines – the Diplomat Mine operated by Forestburg Collieries Ltd., and the Highvale, Roselyn, Vesta, and Whitewood mines operated by Manalta Coal Ltd. (ERCB 1981a: 8-9) (Figure 5). (Within the past year the thermal coal production of the Diplomat Mine has been replaced by coal from the Paintearth Mine, and coal from the Diplomat Mine is now used primarily for domestic purposes.) Based on data provided by the Land Reclamation Division of Alberta Environment, the total acreage disturbed at these five sites as of August 1981 was 7,775 acres, 2,215 acres of which were disturbed between 1976 and August of 1981. During the 1976-1981 time period, 2,195 acres of land were reclaimed. An indication of the agricultural capability of the land

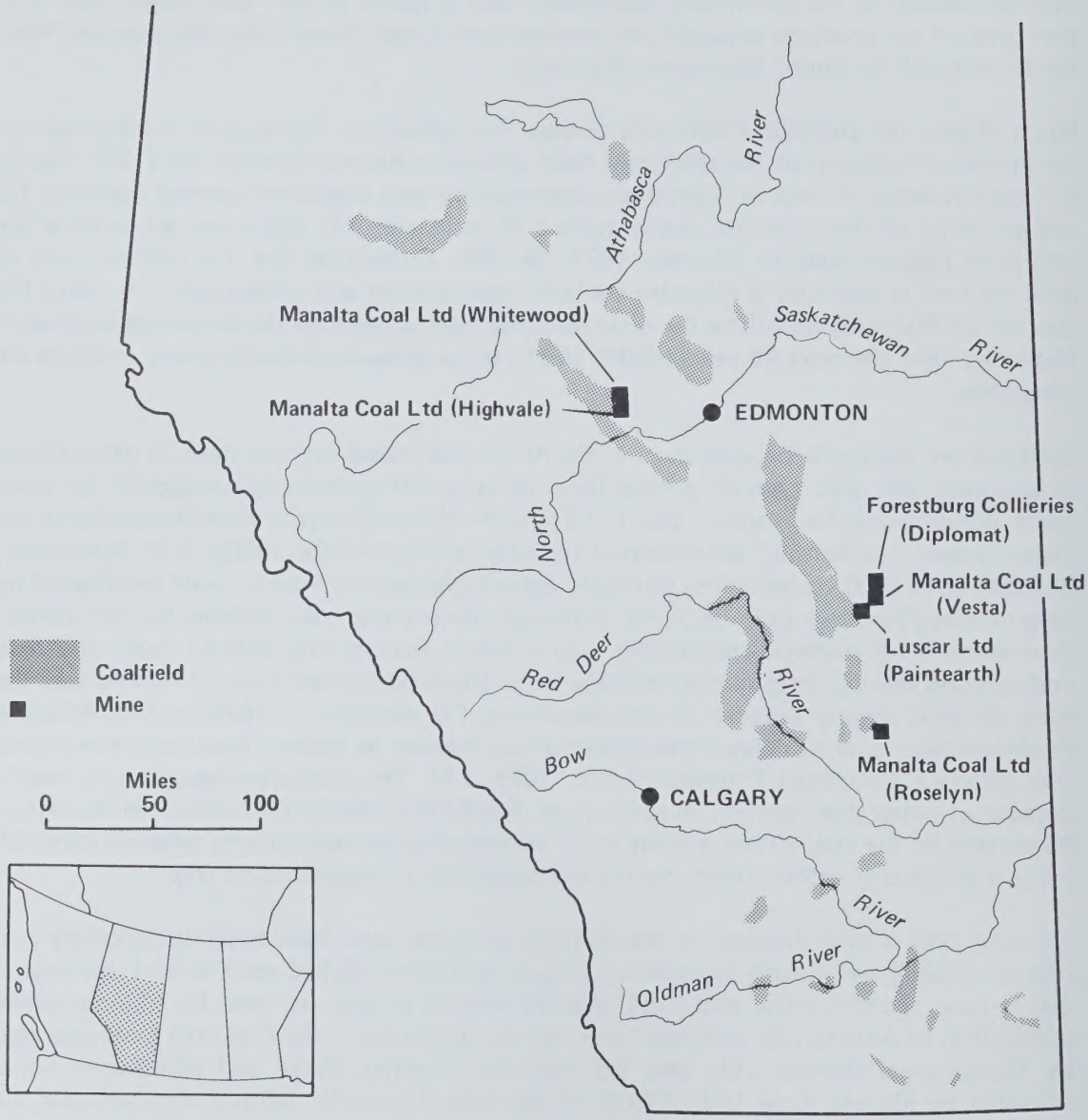

Figure 5. Coal deposits and coal mines of Alberta

Source: ERCB 1980d: Figure 10a and Alberta Energy and Natural Resources Report No. 37 *Natural Resources Inventory Information Index 1980,* page 75.

disturbed by mining is found in Birch (1982). Birch (1982: 68) estimated that 1,895 acres of land were disturbed by surface mining from 1976 to 1980; 63.0 percent of the total was class 1-3 land (Birch 1982: 34). The capability of the land reclaimed during the same time period was not known (Birch 1982: 68). Harrington (1981: 6) estimated that 90 percent of the agricultural land which is disturbed by coal mining is reclaimable within 5 to 10 years of the disturbance.

Legislation and Policies Designed to Conserve Land

Reclamation of all lands disturbed by coal mining is now mandatory. This requirement is spelled out in the Land Surface Conservation and Reclamation Act (RSA 1980, cL-3). The intent of this legislation is to ensure that the detrimental effects of coal mining on agriculture are minimized. Protection of the agricultural land base is more specifically addressed in Alberta's Coal Development Policy. One fundamental feature of the policy is that "no coal development will be permitted to proceed unless in its overall economic and social impact it is clearly beneficial to Alberta" (Alberta Energy and Natural Resources 1976: 12); presumably this feature guarantees that agricultural land will be disturbed only when extraction of the coal is necessary, and when the benefits of extracting the coal outweigh the temporary loss of farmland. The policy also specifies that the Government of Alberta will take particular care when appraising applications for exploration or development in productive or potentially productive agricultural areas. The extraction of coal from under arable lands is not, however, precluded. The Coal Development Policy recognizes four categories of land which define the restrictions placed on coal development. Prime agricultural land in the settled regions of the province, defined in the policy as class 1 and 2 soils, is placed in category 3; in this category the mining company must reclaim the land to productivity equal to or greater than that which existed prior to mining. Other agricultural lands are placed in category 4, which specifies that before this land can be mined there must be assurances for the protection of the environment, and assurances for reclamation. Guidelines issued under the Land Surface Conservation and Reclamation Act spell out what constitutes satisfactory reclamation of disturbed land.

Often coal is found in more than one seam. Recovery of coal from all seams would minimize the amount of land that would have to be disturbed in order to meet Alberta's energy needs. The Coal Conservation Act (RSA 1980, cC-14) is intended to ensure that there is maximum practical recovery of coal without waste of the coal resources being tapped. In many cases, mining the lower coal seams may be economically unfeasible, or physically very difficult. The Energy Resources Conservation Board, which administers the Coal Conservation Act, will not, however, support an applicant's evaluation of mineable reserves on a least-cost basis. The Board (1977b: 11-16) believes that greater emphasis should be put on the recovery of coal from lower seams.

Land Reclamation

Reclamation of mined-out lands can help to ensure that Alberta's immediate energy needs are compatible with a desire to maintain the agricultural land base. Reclamation has been a legislated requirement in Alberta since 1963, when the Surface Reclamation Act was passed. There were, however, several deficiencies in the Surface Reclamation Act. For example, the

Act applied only to surveyed lands, and not to lands within forest reserves or to surveyed land where the surface lease or right of entry was terminated prior to the survey date. Also, the Act only provided for reclamation at the time of mine abandonment. In 1973, the Surface Reclamation Act was superseded by a more comprehensive piece of legislation, the Land Surface Conservation and Reclamation Act (RSA 1980, cL-3). Among other matters, the Land Surface Conservation and Reclamation Act provides for reclamation of surface operations as varied as coal mining and archaeological digs in all parts of the province, reclamation plans before the surface disturbance begins (the operators must post a security deposit to ensure reclamation of the land), reclamation of old abandoned surface operations, and research into reclamation.

Although reclamation has been legislated for close to 20 years, reclamation technology is still young. Because Alberta's energy requirements are immediate, approvals for surface disturbances are being granted when the most suitable reclamation materials and procedures are not known (Harrington 1979: 263; Williams 1981: 20). This raises the danger that the soil's productivity is being compromised by the immediate need to extract coal.

Some experimental results suggest that cautious optimism about restoration of mined lands is warranted. Pole et al. (1979: 139) noted that, in North Dakota, yields of wheat and corn silage showed a positive response to increasing topsoil thickness on reclaimed land, and that yields generally improved over four years of study. Railton (1977: 34) observed that hay yields on reclaimed land at Lake Wabamun in Alberta were comparable in quality and quantity to those on surrounding farmland. Williams (1981: 84) observed good crop yields on reclaimed land near Forestburg, Alberta. But since ten years or more are probably required to fully reclaim a soil (Shaneman 1977: 100; Williams 1981: 53), the successes that have been recorded so far in Alberta may not be long-term successes. Many of the experiments on reclaimed soils have shown good yields of forage crops. But a question remains to be answered: can the reclaimed soil subsequently support cereal crops?

Full reclamation of soils is difficult because many changes in the physical characteristics of the soil result from the mining process. Strip mining reduces the capacity of soils to accumulate water (Carvallo et al. 1979: 158; Williams 1981: 48; Laidlaw 1977: 64); since many soils in the Plains region of Alberta show a soil moisture deficit under natural conditions, mining the coal under such soils would even further reduce the suitability of these soils for agriculture. Reclaimed soils are often subject to erosion by slumping, *piping* (Williams 1981: 21), and runoff. Erosion of soils results in reduced soil productivity, and makes the establishment of new plant communities difficult. Reclamation is particularly hard when saline and sodic spoil materials end up near the soil surface after the mine pits have been refilled.

The salts within saline spoils which are not sufficiently buried slow down reclamation by interfering with the ability of plants to absorb water and nutrients from the soil. This problem also exists when sodic spoils are deposited near the soil surface. Sodic materials, however, create additional problems. Structure problems are characteristic of sodic soils. In sodic soils the clay particles have a strong tendency to repel one another. Dispersed clay particles are undesirable because under dry conditions they tend to form hard crusts on the

surface of the soil. The crusts create environmental conditions which impede the re-establishment of plant cover. For instance, it is difficult for plant roots to penetrate the hard crusts or for seedlings beneath the crust to emerge. The hard soil surface decreases the rate of water infiltration into the soil, thereby making the soil droughty and more susceptible to erosion by surface runoff (Techman Ltd. 1977: 34). There are techniques available for reclaiming both saline and sodic spoil areas, although the present effectiveness of reclaiming areas with sodic spoils has been questioned (Williams 1981: 49). Continuing difficulty in reclaiming sodic soils is of concern in Alberta because the parent material of most soils over the Plains coal fields is derived from saline clay geological deposits – the Belly River, Bearspaw, and Edmonton geological formations. The Alberta Government, through the Land Conservation and Reclamation Council, is sponsoring research on the reclamation of soils which have saline and sodic parent materials.

The problem of saline and sodic spoils being placed near the soil surface is one aspect of a larger problem, that of rebuilding a soil profile in the process of reclamation. In many cases, the soils of a reclaimed area can only be as productive as those before mining if they are restructured in the same way, although there is some loss of fertility during stockpiling.

Restructuring the soil can only be accomplished by carefully removing each soil layer prior to mining and replacing it in exactly the same order after the coal has been extracted. The more often materials have to be handled, however, the greater is the cost of mining. Williams (1981: 24, 57-58) observed a range of $1,000 to $22,000 per acre in the costs of reclamation at various mining sites in the United States and Canada. Techman Ltd. (1977: 74) estimated that the minimum cost of selectively handling one foot of topsoil and four feet of subsoil in Alberta would be $6,000 per acre. A higher degree of materials handling would result in even greater costs. The consumers ultimately pay for the extra costs, usually through electricity utility bills, since most Plains coal is used to generate electricity. Goettel (1977: 107) estimated that if the cost of reclamation was $3,700 per acre, reclamation would cost the average domestic consumer less than $2.00 per year, the average farm user $3.00 per year, and the average industrial user $44.30 per year. The success of mine-site reclamation partly depends on what industry and the public-at-large is willing to pay for coal.

When the Land Conservation and Reclamation Council, which is composed of representatives from government departments, local authorities, and regional planning commissions and which oversees reclamation projects within the province, feels that the mined-out land has been reclaimed, it issues a reclamation certificate to the mine operator. One reclamation certificate has been issued so far.

Even though there is legislation requiring that mined areas be reclaimed, and even though the rudiments of reclamation technology exist, there is no assurance that mined-out areas can or will be returned to agricultural use. More than just the soils must be restored in order for agriculture to be feasible. For instance, a suitable water supply is essential to most farming operations. Coal seams are often good groundwater aquifers from which farmers obtain water. How successful re-establishment of the groundwater regimes after mining can be, is unknown. Changes in the supply of water on the reclaimed land and in surrounding areas might be expected, since mining will result in changes in the hydraulic properties and

infiltration patterns at the site (Alberta Environment 1980: 10). Especially where the groundwater aquifer is in or above the coal seam prior to mining, the groundwater will be in contact with mine spoils after reclamation. The subsequent reduction in water quality could be severe in areas where coal ash from a thermal power plant was put in the bottom of a mine pit. So far, studies at the Whitewood Mine near Lake Wabamun have shown only a slight reduction in groundwater quality where coal ash is put in the deeper mine cuts after mining (Alberta Environment 1980: 73-75). Furthermore, use of the groundwater may be stalled even if the groundwater is suitable for use, because it is difficult to drill a well in spoil (Alberta Environment 1980: 91). Another requisite for the establishment of successful agriculture on a mined-over area is ground that has subsided enough to support farm buildings. How long it would take for spoils in Alberta to stabilize is unknown, but studies elsewhere have suggested that two or three years may be sufficient. Special building techniques could obviate the problem of waiting for the ground to subside (ERCB 1979b: 20-21), but using such techniques would add to the cost of agriculture. The cost of using special building techniques could instead be added to the cost of mining, if it is the intent of Alberta's Coal Development Policy to include farm buildings as one of the features needing replacement or rehabilitation in order to return the land to its former use.

In addition to technical problems which militate against re-use of mined lands for agriculture, there are no firm provisions in the legislation and policies governing reclamation in Alberta guaranteeing the return of mined-out agricultural lands to agriculture. Instead, Alberta's Coal Development Policy states that "the primary objective in land reclamation is to ensure that the mined or disturbed land will be returned to a state which will support plant and animal life or be otherwise productive or useful to man at least to the degree it was before it was disturbed" (Alberta Energy and Natural Resources 1976: 7); the goal of reclamation, as stated in the reclamation guidelines, is "the return to, or the continuation or resumption of some appropriate land use upon the conclusion of the surface disturbance" (Alberta Environment 1977: 1). Reclamation is most successful when the end land use, developed by the proponent in consultation with government, is known before the mining begins. Decisions regarding use of the land after reclamation are made by Alberta Energy and Natural Resources in cases where the land was owned by the Crown prior to mining, and by the regional planning commissions, local municipalities, and counties in cases where the land was privately owned prior to mining (Harrington 1979: 264-265). Although the primary intent of these agencies will be to return the land to farm uses if farming was the land use before mining, returning the land to farm uses is not guaranteed.

OIL AND NATURAL GAS EXPLORATION AND EXTRACTION

Drilling Spacing Units and Target Areas

The geological formations in which oil and gas are found do not conform to surveyed surface boundaries. Ground survey co-ordinates are, however, used to describe the underground location of oil and gas rights purchased from the Government of Alberta. The lease is sized to efficiently extract hydrocarbons from the ground. Since natural gas is much less viscous than oil, wells to extract natural gas need to be spaced less closely together than do oil wells. Even spacing of the wells helps to ensure even withdrawal of hydrocarbons.

The minimum size of a lease for each productive well is designated by the Energy Resources Conservation Board, and is known as the Drilling Spacing Unit (DSU). DSUs have been designated by the Board to prevent excess well drilling. Within each DSU there is an area called the target area, which is designated for well drilling activity. On January 1, 1968 the normal DSU for a gas well was established as one section (640 acres) with the target area located 1,320 feet inside and parallel to the sides of the DSU (Figure 6). The normal DSU for oil wells was a quarter section with the target area located 660 feet inside and parallel to the sides of the DSU (Figure 7). The target areas of the gas and oil wells overlapped in four places (Figure 8). This was the basic oil and gas DSU pattern until September 1, 1981. The size of each overlapping area was 10 acres. Since a company drilling an exploration well frequently does not know beforehand whether a geological formation contains oil or gas, drilling within the overlapping areas allows the company to be on target for either oil or gas.

There are, however, deviations from the vertical, as the well is being drilled, that amount to about two percent of the vertical distance from the ground surface to the hydrocarbon deposit. To avoid completing the well outside the target area, drilling was set back within the surface target area. For example, suppose there were a hydrocarbon deposit 4,000 feet below the ground surface. To ensure that the drill hole was within the target area when it hit this deposit, the well would have to be drilled at least 80 feet inside the surface target area boundary. This effectively reduces the ground surface target area from 10 acres to about 5.7 acres, and narrows the choice of well sites suitable to the farmer. In developing already defined oil or gas pools the overlapping target area is not an important feature, since the full 160-acre gas target or the full 40-acre oil target can be used.

Logical as this system of exploration regulations was from the oil well driller's point of view, centre-drilled wells presented farmers with many problems. One was the inflexibility of locating an exploratory well because of the regulations governing target areas. Topographic or other constraints could further narrow the choice of a well location to sites that were unsuitable to the farmer. Another problem for farmers was the lost production from the well sites and access roads. Based on a 400 by 400 foot oil well site and a 1,320 by 40 foot access road, 212,800 square feet (4.9 acres) out of each quarter section would be lost to farm production; often, however, the oil companies use much less than the 4.9-acre lease once the well is producing. The greatest impact on farming, however, was the increase in time and money needed to farm a field that was divided by a well site and access road.

The extra costs of farming around the well site and access road were due to:

1) The creation of a headland (turning area) around the well. A field with a well site in it necessitates more turning of farm equipment than a field without a well site (Figure 9). Increasing the number of turns increases the time needed to work the field.

2) Overlap of field operations on the headland. Overlapping results in the use of more seed, fertilizer, and herbicide than would be the case if machinery were travelling in a straight line, and in a reduction in yield on the headland (Hanus 1980b: 22).

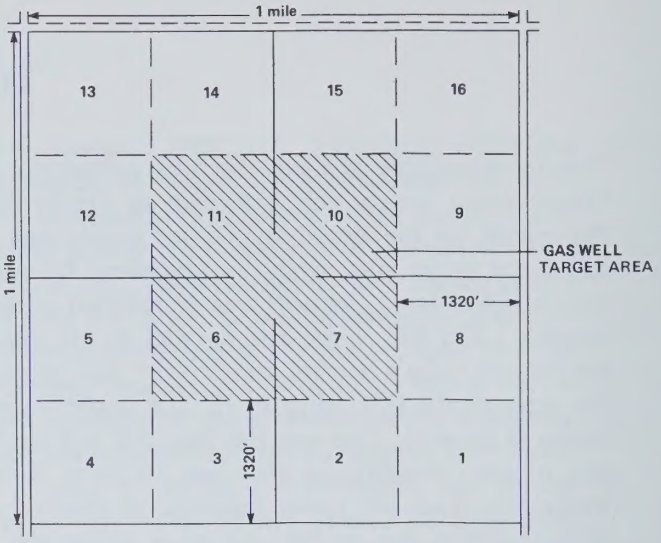

Figure 6. The normal designated spacing unit and target area for a gas well, January 1, 1968

Source: ERCB 1978: Figure 3

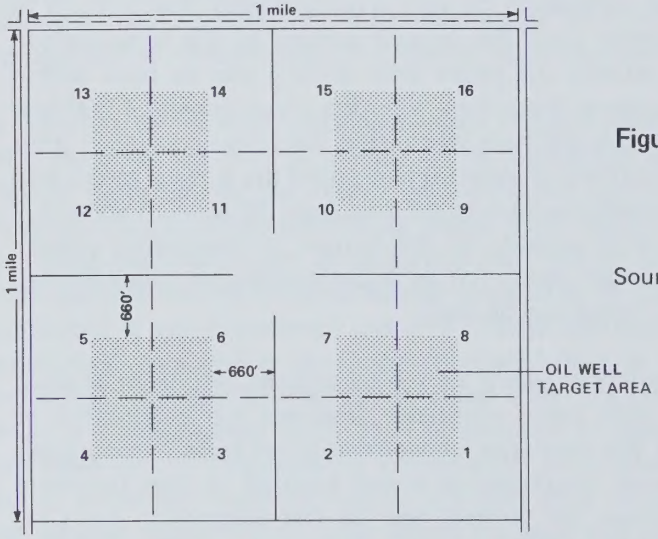

Figure 7. The normal designated spacing unit and target area for an oil well, January 1, 1968

Source: ERCB 1978: Figure 2

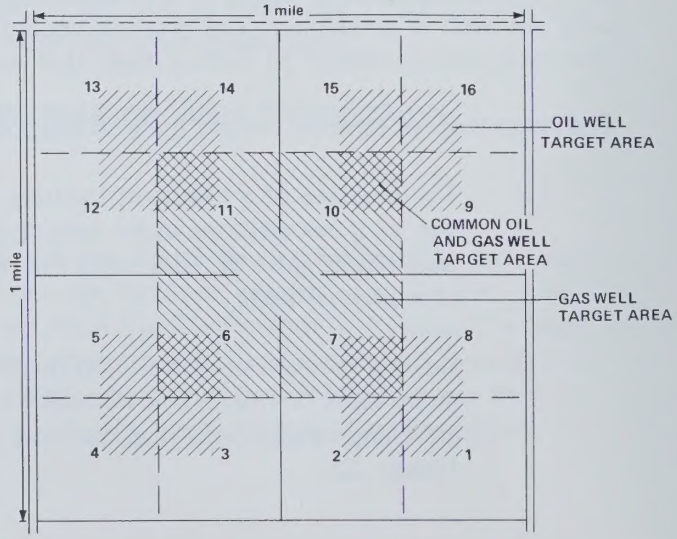

Figure 8. The overlap of oil and gas well target areas, January 1, 1968

Source: ERCB 1978: Figure 4

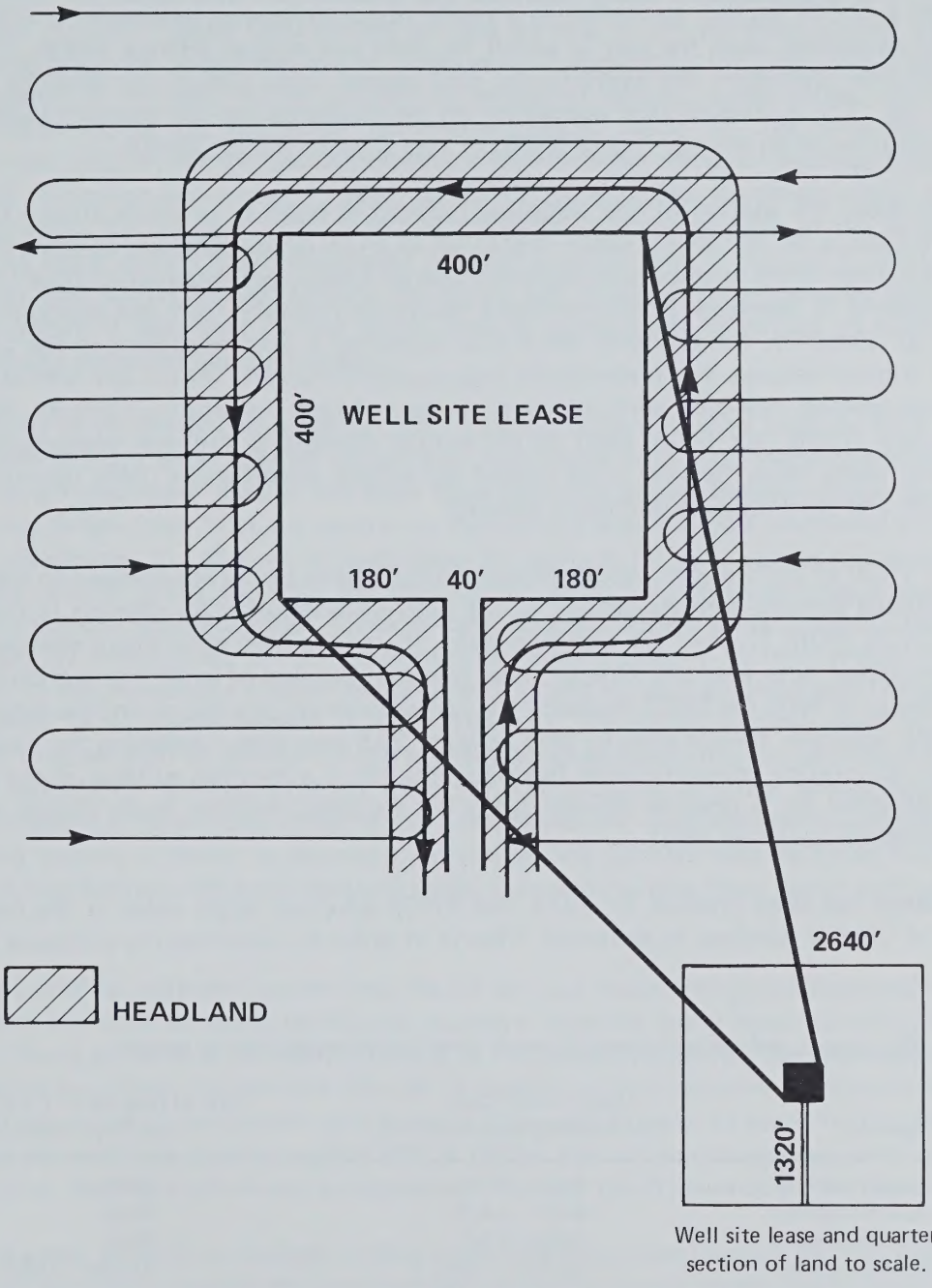

Figure 9. The increase in the number of turns of farm equipment caused by a well site and an access road*

Source: Hanus 1980b: 24

*Perpendicular field pattern is illustrated

Hanus (1980b: 23) assumed nine field operations for a cultivated crop and six field operations for a summerfallow field and then estimated the extra costs to farming resulting from the interference of the well site and road. The extra time needed for a grain-growing operation on a quarter section amounted to a yearly opportunity cost ranging from $241.79 to $970.62 depending upon the way in which the field was worked (Hanus 1980b: 37); for a summerfallow operation the opportunity cost ranged from $95.21 to $408.04 (Hanus 1980b: 38). The overlap of field operations on the headlands and the resultant yield reductions amounted to an average cost of $300 per year (Hanus 1980b: 39-40).

In some areas the spacing of the wells was reduced in order to properly drain a reservoir of more viscous oil. A Spacing Order is granted to an oil or gas company to space the wells closer together, if the operator convinces the Energy Resources Conservation Board that the closer spacing is necessary to economically maximize recovery from the reservoir (ERCB 1977a: 3). Recently, for example, the ERCB approved a 40-acre spacing in the Lindberg area of Alberta because it is underlain by high-viscosity crude oil (heavy oil) (ERCB 1981c: 1). Closer spacing, however, adds greatly to the cost of farm operations (Table 8). Although the Surface Rights Act (RSA 1980 cS-27) entitles farmers to full cash compensation for these and many other farming costs caused by surface disturbances, farm operations are disrupted, and total food production is reduced.

Section 4.030 of the Oil and Gas Conservation Regulations allows applications to the ERCB by individual farmers, farming groups, or the petroleum industry for changes in the target areas (ERCB 1978: 1). Over the past few years, there have been some major changes which have benefitted farm interests. One of these was the adoption of larger one-section gas well target areas. In 1978, the ERCB increased the common target area for oil and gas exploration from four separate 10-acre sites to four separate 22.5-acre sites. Increasing the target area gave the exploration company more flexibility to drill in a location suitable to the farmer, and it provided for a possible 80-acre fence line location. Another major change was the adoption of corner target areas.

This change has been gradual. In 1974, the ERCB adopted target areas in the northeast corner of quarter sections in southeast Alberta in order to minimize the problems central

Table 8. Well spacing and the added costs of yearly farm operations per quarter section

Spacing	Opportunity Cost of Working Headland*	Cost of Overlap of Field Operations and Yield Reduction**
1 well/quarter section	$242 - 971	$299
2 wells/quarter section	$407 - 1,423	$620
4 wells/quarter section	$820 - 2,347	$998
16 wells/quarter section	$3,231 - 3,693	$1,554 - 2,685

Sources: Hanus 1980b, Hanus 1981.

* 1981 custom rates

** Net crop value equals $150 per acre

target areas presented for irrigation, especially sprinkler irrigation. In 1980 the ERCB approved northeast target areas for quarter section spacings in the Grande Prairie area. To encourage the well to be located as close as possible to the corner of the quarter section, the Board divided the target area into primary and secondary areas. The primary area is an area 218.7 yards by 218.7 yards (200 metres by 200 metres) in the northeast corner of the spacing unit, with the remainder of the target area designated as the secondary area; the actual location of the well can be decided by reason of geology, conservation, or equity (ERCB 1980b: 4), or on landowner preference (ERCB 1980b: 6). The only common primary target area for oil and gas exploration is the northeast corner of legal subdivision 6 (Figure 10). Effective September 1, 1981 the ERCB adopted the northeast corner target area designations for all new wells drilled in the White and Yellow areas of the province, exclusive of lands within Board-designated oil pool boundaries as of August 1, 1981, and exclusive of land within Spacing Orders. The Board will, however, allow variances from this regulation where it feels that mixing target areas in substantially developed oil pools will result in equity problems between leasees.

The adoption of northeast corner target areas is generally beneficial to farming. With only one common primary target area for oil and gas, exploration drilling normally occurs on one common target site rather than on the other three sites. For normal quarter-section spacing, changing the target areas from the centres to the corners results in less land being used for roadway allowances; the amount of land saved for agricultural use is about two acres per square mile (ERCB 1977a: 8). Also, the time needed to farm around a well site is reduced. Alberta Agriculture estimated that it would take 36 minutes less using a parallel farming pattern, and 97 minutes less using a perpendicular farming pattern, to farm around a well site placed in the corner of a quarter section than it would to farm around a well site placed in the centre of a quarter section (ERCB 1981d: 7). The saving in time could be very significant in areas such as northern Alberta where weather conditions can be critical to the timing of agricultural operations (ERCB 1981d: 7). The adoption of corner targets, however, is likely to result in wells being closer to farm structures; the noise and traffic generated by the drilling activity is likely to be more noticeable, and farmers may be more likely to experience interference with groundwater supply, than was the case when centre drilling was the norm.

Some more conflict between farmers and the oil and gas industry might be expected in the future when attempts are made to improve recovery from the many heavy oil pools in the province. There are several different methods of "enhanced recovery," but normally more wells have to be drilled. For example, the use of thermal tertiary recovery schemes in heavy-gravity oil pools would necessitate well spacings of approximately 10 acres; that is, 16 uniformly spaced wells per quarter section (ERCB 1981d: 18). In an extreme case such as this, it is doubtful that agriculture and enhanced oil recovery could co-exist on the same land.

In unusual cases, directional drilling (drilling a well from a surface location on the periphery of a quarter section, or outside the parcel of land, to the geological target area) is sometimes warranted. Directional drilling is a desirable alternative for farmers because access roads of only minimal length are necessary (ERCB 1981d: 13) and because several wells can be drilled from a drilling pad which is only somewhat larger than a drilling pad for one vertical

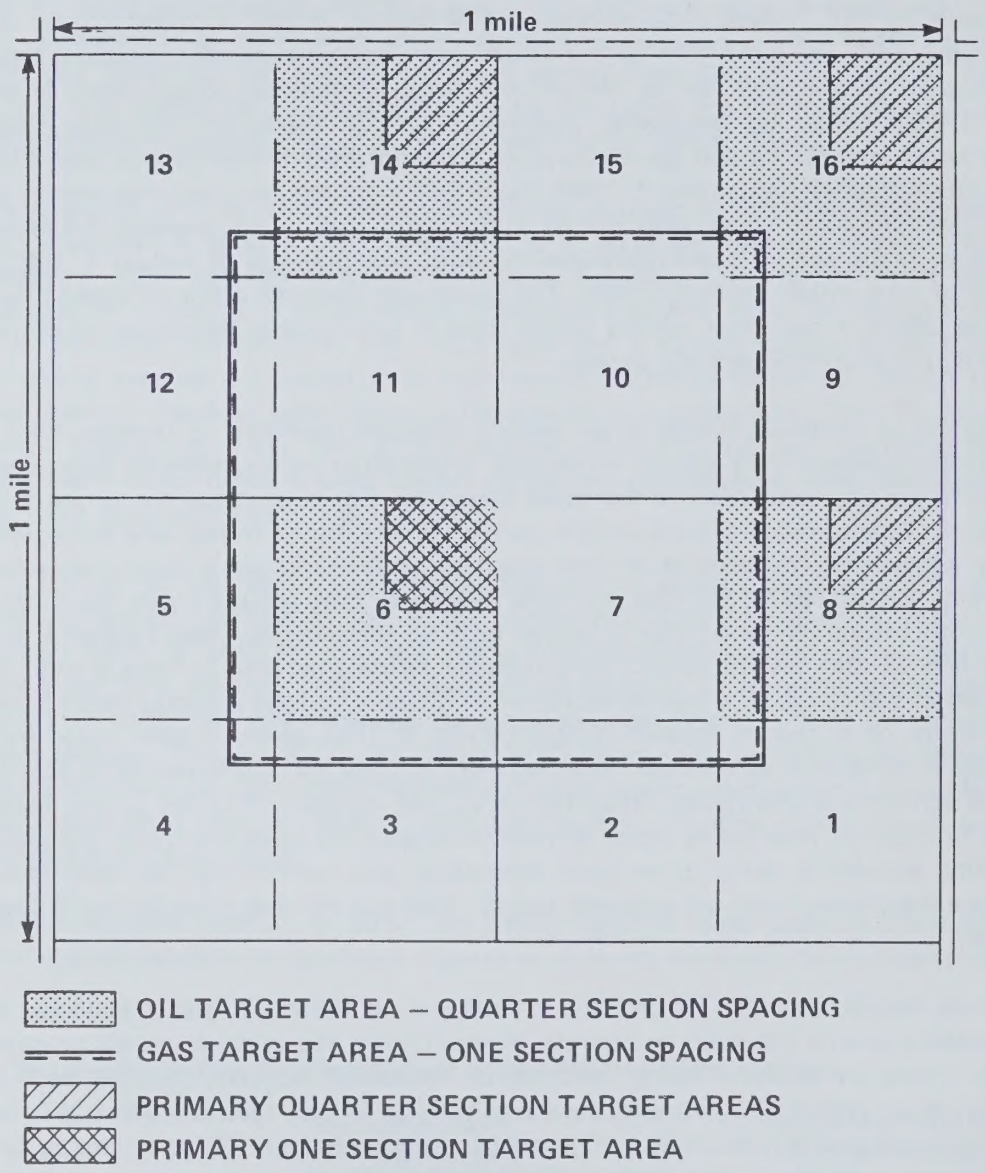

Figure 10. The normal designated spacing units and target areas for oil and gas wells in the White and Yellow areas of Alberta, September 1, 1981*

Source: ERCB 1981d: Figure 7

*In 1981, the ERCB increased the gas target area for a section from 2,640 feet by 2,640 feet (one quarter section) to 2,970 feet by 2,970 feet, to improve flexibility and the opportunity to solve land-use problems.

well. There are, however, many reasons why directional drilling is not used very often. Directional drilling adds 30 to 60 percent to the cost of a well and increases the risk of mechanical failure (ERCB 1977a: 10). In heavy oil areas of Alberta, directional drilling is very difficult because the deposits are typically located close to the ground surface (ERCB 1981d: 8) and because non-vertical well bores result in excessive wear on the rods and casings of the pumps needed to remove the heavy oil from the ground (ERCB 1974: 77). In addition, in heavy oil areas directional drilling does not eliminate the need for some drilling pads in the farm field (ERCB 1981d: 8). Because of the costs of directional drilling, the ERCB believes that decisions to directionally drill wells "should be evaluated on a site by site basis having regard for specific technical, economic, resource recovery and land-surface considerations" (ERCB 1981d: 16).

Impact on the Land Base

The oil and gas industry has significantly affected agriculture by temporarily removing land from agricultural use. Harrington (1981) assumed that each well site occupied four acres of land, and estimated that 108,800 acres of agricultural land are occupied by active wells, 96,000 acres have been abandoned and have yet to be reclaimed, and 69,120 acres have been abandoned and reclaimed; there is nearly three times more agricultural land still out of production than land that has been used and reclaimed. Unreclaimed land is that for which no reclamation certificate has been issued, either because the drilling activity took place prior to 1963, when no reclamation was required, or because the leases are still active and are only partially reclaimed. Data obtained from the Resource Economics Branch of Alberta Agriculture indicates that from 1976 to mid-1981 nearly 108,000 acres of land in the White and Yellow areas of Alberta were used for drilling (Table 9). Nearly 35 percent of the total, 37,647 acres, was class 1-3 agricultural soils. At the same time, about 15,000 acres were abandoned; the number of abandoned acres reclaimed is unknown. This data assumes that 4.5 acres per well site were removed from agricultural production. In both sets of data, the amount of land removed from agricultural use may be overstated. Often the petroleum companies let the farmers use a good portion of the leased area once drilling is completed and production begins. Then the amount of land not available for farming usually consists of the roadway and a small area around the wellhead and does not exceed two acres.

Other Effects and Hazards

The land use problems presented to farming by oil and gas wells many be compounded by accidental spills of formation fluid. Considering the number of wells that have been drilled and the volume of petroleum hydrocarbons extracted each year, the number and volume of spills is not large. For instance, in 1979 there were about 650 oil and salt water spills; 110 of these spills were in excess of 1,260 barrels (ERCB 1980a: 21). The effect on the soil where such spills occur, however, can be very severe.

Formation fluid consists of two main substances: hydrocarbons and salt. To a lesser degree, *mercaptans* and hydrogen sulphide are present in sour oil and gas fields. Although the effect of these substances varies, generally speaking, they are detrimental to the soil because they alter the soil's physical and chemical properties and because they kill organisms living in the soil.

Table 9. Amount of land used for drilling activity in the White and Yellow areas of Alberta, 1976 – mid-1981

CLI Soil Classification	Acres of Land Used
Class 1	3,933
Class 2	13,527
Class 3	20,187
Class 4	28,661
Class 5	20,651
Class 6	7,241
Class 7	927
Organic	12,654
TOTAL	107,781

Source: Research Economics Branch, Alberta Agriculture

Oil spills change the physical structure and the nutrient status of soils; such changes are discussed in more detail on pages 31 and 32 of this report. Oil in fact consists of many different types of hydrocarbons, the toxicity of which is partly related to their solubility in water (Shaw n.d.: 2-6). Hydrocarbons with high solubility tend to be more toxic than those with low solubility in water.

The other main formation substance to detrimentally affect the soil is salt (Shaw n.d.: 13-17). Salt causes the dispersion of clay particles within soils. The dispersed clay tends to block the movement of air and water into the soil. Anaerobic conditions so created can result in the suffocation of many beneficial soil organisms. Under the same conditions, there is a tendency for sulphate-reducing bacteria to thrive. These bacteria produce hydrogen sulphide, which is lethal to plants and many soil animals. Salt in the soil also interferes with the uptake of nutrients and water by plants.

Hydrogen sulphide and mercaptans are highly soluble in water and very poisonous (Shaw n.d.: 12). Soil animals and plants could be killed by hydrogen sulphide and mercaptans dissolved in soil water, but even during oil pipeline ruptures, the hydrogen sulphide and mercaptans generally rise to the ground surface and dissipate into the atmosphere. The greater danger of these gases is that nearby farm animals could be killed during large sour gas or sour oil well blow-outs, or during large pipeline ruptures; animals that might normally move away from offensive odors may not do so, since odor sensitivity to hydrogen sulphide quickly decreases. Facilities handling hydrocarbons which contain hydrogen sulphide and mercaptans are subject to setback distances from residential and other developments (ERCB 1979b).

To reclaim a soil on which there has been a spill of formation fluid is complex because the component substances must be treated differently. Ploughing and fertilizer applications are the main ingredients of the successful reclamation of soils after oil spills, these measures help soil micro-organisms to degrade the oil. Salt spills are much more difficult to reclaim, partly because salts are not degradable by soil micro-organisms (Blauel and Hocking 1974: 19; deJong 1979: 44-45). Salt spills are reclaimed with varying degrees of success by adding

calcium to the soil and then flushing the soil with water. Flushing out the sodium may be accelerated with irrigation and associated drainage systems, but since most spill areas are small, the construction of such systems is not usually economically feasible (deJong 1980: 84). The difficulty in reclaiming salt spills is disconcerting because the yearly volume of salt water spilled already exceeds the volume of oil spilled, and both the volume and frequency of salt water spills are expected to increase as the oil fields are depleted (deJong 1979: 44-45; deJong 1980: 80). In a few cases, severe reclamation problems are encountered around earthen pits near battery sites because the pits were used to store both brine and oily wastes, and sometimes because the sites were chemically sterilized.

One petroleum industry practice which can contaminate soils is the disposal of drilling muds, which consist basically of water and clay. Some chemicals are added to drilling muds for a variety of reasons. Caustic soda is added to control the pH of the mud. Other chemicals such as starch and tannin, and preservatives, are respectively used to control viscosity and to prevent bacterial degradation of the mud. For deeper wells, which are not common in the Plains area of Alberta, more complex mud mixtures are required. The disposal of drilling muds is regulated by the ERCB (1975). In most cases, the mud is disposed of in pits on the drilling site, and the pits contain less than 6,000 barrels of drilling mud. Offsite disposal is possible when the sump fluids meet specified chemical criteria and when the disposal site and methodology are approved by the landowner and the ERCB.

Disposal sites are reclaimed when drilling ceases. The process usually involves in-filling the sump so that the water in the drilling mud is "squeezed out" and flows over land on the lease site. The disposal site is then covered with stockpiled topsoil.

The petroleum industry may impact upon farming by altering farm water supplies. In a few cases, drilling for oil and gas has affected the quality and quantity of groundwater available to nearby farms. Drilling regulations which specify that wells must be cased are intended to prevent changes in groundwater availability. In enhanced recovery schemes, water is often injected into wells in order to force oil to the surface. In the future, there may be some competition between farmers and the oil industry for water. Competition for groundwater is reduced by regulations which specify that to be used for enhanced recovery, groundwater must be taken from aquifers at least 200 feet deeper than nearby farm water wells. Most deep-well injection occurs in northern Alberta where competition is minimal because surface water is fairly abundant and total farm demand for water is comparatively low. The competition for water is likely to be greatest in areas where water is not naturally abundant and where water use is already high. For example, in 1976 the injection of surface water for enhanced oil recovery was the fourth largest consumer of water in the Battle River basin, using two-thirds the amount of water used for stock watering, and nearly one-third the amount of water used for irrigation (Alberta Environment 1981b: 14). As the oil fields in the White and Yellow areas of Alberta become depleted, the need for injection water will decrease, because less water will be required to replace the diminishing amounts of oil produced.

THE IMPACT OF INDUSTRY ON ALBERTA'S AGRICULTURAL LAND BASE

INDUSTRIAL LAND

Provincial Policies and Industrial Development

The Government of Alberta has adopted two keystone policies which are intended to

1) secure the economic future of Albertans,
2) enhance Albertans' access to employment,
3) increase the incomes and living standards for residents of medium-sized cities and towns, and
4) reduce the costs of growth in Edmonton and Calgary (Ironside and McVey Jr. n.d.: 2).

The keystones are diversification of the provincial economy and decentralization of industrial activity.

Six economic areas were identified as offering good prospects for diversification in Alberta. They were processing of agricultural goods, natural resources processing, research, recreation and tourism, finance, and the traditional role of Edmonton as a gateway to the Canadian north (RDRPC 1979: 7; Ironside and McVey Jr. n.d.: 2). Processing of agricultural produce, and natural resources processing (for example, petrochemical industries) appear to have the greatest potential for affecting the agricultural land base.

The objective of decentralization is to promote the industrialization of smaller centres, not to relocate industry from Calgary and Edmonton or to restrict growth in these cities (RDRPC 1979: 8). The Government of Alberta promotes decentralization by increasing the number of government offices and services in non-metropolitan centres; by encouraging private firms to locate in small communities; by offering financial assistance for small- and medium-sized locally owned firms (RDRPC 1979: 8-10); by funding regional infrastructures to smaller communities, such as the water and sewer lines proposed in the Edmonton Regional Utilities Study (Alberta Environment 1978); by providing grants to smaller communities for the construction of recreational facilities; and others (Yurko 1974: 26).

The policies of diversification and decentralization are effected through various government departments. For example, the Regional Business Development Branch of Alberta Tourism and Small Business plays a strong role in encouraging private firms to locate in smaller communities. The Business Development Branch helps towns prepare economic development plans. Should a community lack the infrastructure to meet its goals, the Alberta Industrial Land Program is available to assist the community in assembling and/or developing industrial land. This program is a co-operative effort between Alberta Tourism and Small Business, which initiates applications from and provides advice to interested municipalities; the Alberta Housing Corporation, which purchases and services the land and administers the program; and the municipality, which markets the land (Alberta Tourism and Small Business 1981: 11). Alberta Tourism and Small Business subsequently promotes the business opportunities available in the communities.

As a consequence of the Government of Alberta's desire for greater diversification and decentralization, the regional planning commissions have been directed by Alberta Municipal Affairs' Rural Industrial Land Use Policy to include provisions in regional plans which allow

rural municipalities more discretion to permit industrial development. Under the policy, industries which can be suitably accommodated in rural areas include

1) those providing products and services to agriculture, for example, feed mills, and bulk fuel plants,
2) natural resource extraction industries, for example, cement plants and natural gas plants,
3) non-labor intensive industries which require large amounts of land and few on-site improvements, for example, storage and handling of pipe and drilling equipment, and
4) noxious industries which are not compatible with urban environments, for example, alfalfa-processing plants and petrochemical industries (Alberta Planning Board 1981: 4-5).

The policy guidelines issued by Alberta Municipal Affairs further stated that, except for industries that are governed by site-specific criteria, location of industries within industrial parks is preferred, and that the selection of locations should be predicated upon principles of sound transportation planning (Alberta Planning Board 1981: 5-6).

The guidelines also recognized the importance of the agricultural land resource. Alberta Municipal Affairs (Alberta Planning Board 1981: 2) recognized the principle that higher capability land should be preserved for agricultural use, and that fragmentation *"should be avoided wherever alternative courses of action are reasonably available" (*emphasis in original).

Decentralization may have only limited success because current policies are not designed to restrict growth in metropolitan areas. Ironside and McVey Jr. (n.d.: 27) argued that for decentralization to be effective, there must be a more restrictive policy on land annexations in metropolitan areas than around smaller urban centres. Annexation policies near metropolitan centres do not now appear more restrictive than those elsewhere (for example, the Edmonton annexation in 1981). Also, decentralization may have only limited success because enticing industrial growth away from larger urban centres is difficult. The difficulty arises for many reasons, including the fact that smaller communities are not large enough to offer the amenities needed to attract employees for industry, and that settlements must be of a certain threshold size to ensure the success of an industry. These reasons are recognized in Alberta Municipal Affairs' (Alberta Planning Board 1981: 3-4) policy guidelines on rural industrial land use (Alberta Planning Board 1981: 3-4). The document states that labor-intensive industries, or those which are very dependent upon other nearby industries, should continue to be accommodated within urban communities. (For similar reasons, within the Red Deer Regional Planning Commission area, even the movement of Alberta Government offices and services has tended to support larger cities and towns (RDRPC (1979: 8)). Although the policy guidelines on rural industrialization are a vehicle for decentralization, and as such may allow some smaller centres to maintain their relative position in Alberta's urban hierarchy, they do not preclude the concentration of industrial growth near larger urban and metropolitan areas.

What this trend will mean for the future of the agricultural land base in Alberta is unknown. Based upon past trends, it could mean that the good agricultural land near Alberta's largest urban centres will continue to be used up, and depending upon the way the policy guidelines

on rural industrialization are implemented, that good agricultural land in rural areas will also be used for industry. Nevertheless, the policy guidelines could also allow for the conservation of good agricultural land by deflecting onto less productive land in rural areas industry which would otherwise locate on good agricultural land near urban centres.

Regional Planning Commissions and Industrial Development

As local governments compete with one another to fulfil their industrial aspirations, conflicts between them could develop at the expense of the agricultural land base. Increasingly, the role of the regional planning commissions would be one of trying to co-ordinate the industrial aspirations of local governments. One recent example of conflict occurred in the Red Deer area. In 1980, the County of Red Deer approved two area structure plans for industrial and commercial purposes comprising a total area of 848 acres. The approval was of concern because:

1) the land approved by the County was close to the city of Red Deer. This would make the marketing and development of industrial land in the city more difficult, and

2) the County's structure plans conflicted with the city's municipal plan. The municipal plan favored the development of unserviced land for agriculturally oriented industry in the urban fringe, while the County's industrial land was to be used for a diversity of industries.

The Red Deer Regional Planning Commission is trying to minimize conflicts between the City and County of Red Deer by encouraging the adoption of a joint general municipal plan. Such a plan would also serve to protect good agricultural land as long as possible by guiding development to areas containing lower capability soil. Were the City and County of Red Deer to continue to independently pursue industrial and commercial growth, more land would be dedicated for industry than necessary to meet the demand; this would probably mean unnecessarily large amounts of land prematurely taken out of agricultural production.

It is difficult to see how effective the planning commissions can be in conserving agricultural land when there are few specific commission policies and few provincial policies concerning the conversion of agricultural land to higher density urban land uses (Alberta Municipal Affairs 1978: 5-7), and when most municipalities, often supported by regional planning commissions, also encourage economic development. When, for example, the people within the Red Deer Regional Planning Commission area were surveyed in 1979, they ranked various environmental concerns as the four most important objectives to be addressed in future regional policies (RDRPC 1980: 6). The highest ranking of these objectives was to minimize the loss of arable land. The desirability of preserving prime agricultural land was addressed in the Commission's *Proposed Regional Plan* (RDRPC 1981: 12-13). To satisfy the economic aspirations of people in the region, the proposed plan (1981: 31) also states that the Commission will encourage expansion of primary resource industries; further upgrading of oil, natural gas, coal, and other resources; and the expansion of light secondary manufacturing, as well as other economic developments. Economic goals such as these are difficult to reconcile with maintaining the agricultural land base of the Red Deer region, even though conservation of agricultural land is a major objective of the people there.

Impact of Industry on the Land Base

Data on the amount and quality of land used for industry is difficult to obtain. An approximation of the amount of land recently dedicated to industrial parks was obtained from the *Alberta Locations* industrial inventory compiled by Alberta Tourism and Small Business, and from the "Report on Industrial Sites" in the June 8, 1981 edition of the *Globe and Mail.* In all of Alberta, the total size of industrial parks with some land available for occupancy is approximately 47,500 acres. In many cases, not all of the land within newer industrial parks is available for immediate purchase. Some lots, for instance, may require servicing before they are sold. Only 26,000 acres of the 47,500-acre total are currently available for use. The above totals include land in rural areas, and land in urban municipalities.

A revealing pattern emerges when the ten areas with the largest amounts of land allocated for industrial use are ranked (Table 10). These ten locations, out of a total of 124, accounted for 29,275 acres, or 61.6 percent of the Alberta total. Six of the ten areas were in Edmonton or its environs. The acreage of industrial parks in these six areas alone was 20,812 acres, or 43.8 percent of the Alberta total. All but Medicine Hat and Slave Lake are located in the Edmonton-Calgary corridor.

Insight into the quality of land being used for industrial parks can be gained by examining the applications to the regional planning commissions for commercial/industrial subdivision of agricultural land. Some of the subdivision is for industrial parks and some is for individual parcels of commercial/industrial land. From 1976 to 1980, the amount of land approved for such use was 11,543 acres (Birch 1982: 52). Slightly less than 61 percent of the total was class 1-3 land. Assuming that these percentages could apply equally well to the total size of industrial parks, nearly 29,000 acres of class 1-3 agricultural land have recently been, or will shortly be, used for industrial parks.

Table 10. Size of industrial parks in ten areas of Alberta with the largest amount of land available for occupancy

Location	Size of Industrial Park (acres)
Edmonton	7,640
County of Parkland	5,590
Medicine Hat	3,840
Fort Saskatchewan	2,968
Spruce Grove	1,920
Calgary	1,755
Red Deer	1,518
Namao	1,383
Slave Lake	1,350
County of Strathcona	1,311
TOTAL	29,275

Much of the commercial/industrial subdivision activity occurred in the Edmonton-Calgary corridor area (Table 11). There, a total of 7,452 acres, or 64.6 percent of the provincial total, were subdivided for commercial/industrial uses. Of this total, 4,969 acres were class 1-3 land. Two-thirds (weighted average) of the land subdivided within the corridor was very productive class 1-3 land. Avoidance of high-quality agricultural land for commercial/industrial uses in the Edmonton-Calgary corridor is not generally apparent. Eight of the 12 administrative units in the corridor showed percentages of class 1-3/class 1-6 land subdivided for commercial/industrial uses greater than the class 1-3/class 1-6 percentage for the administrative unit as a whole.

The concentration of industrial land in the Edmonton-Calgary corridor, particularly within commuting distance of Edmonton, suggests that wide dispersal of industrial activity is difficult. The advantages of transportation links, built-up infrastructure, labor force, and services make the corridor and the Edmonton region a powerful magnet for industry. Unfortunately, the corridor north of Red Deer, the most attractive area for industry, also contains the best farmland in Alberta. The results of the decentralization policy so far have not provided any protection from industrialization for high-quality farmland and seem unlikely to do so in the future. If the locational advantages of the corridor remain, which seems probable, the alternative of locating industrial development on the poorer soils in the corridor should be explored, if conservation of agricultural land is an objective.

Table 11. Acreage of land subdivided for commercial/industrial purposes in the Edmonton-Calgary corridor, 1976-1980

Administrative Unit	Acreage of All Land Classes	Acres of CLI 1-3 Land	Percent CLI 1-3/CLI 1-6 Land Used for Commercial/ Industrial	Percent CLI 1-3/CLI 1-6 in the Administrative Unit*
Co. Strathcona	1,224	1,092	89.2	62.0
Co. Leduc	1,152	896	77.8	65.5
Co. Parkland	1,037	546	53.6	46.7
M.D. Sturgeon	1,001	825	90.9	81.2
Co. Wetaskiwin	874	404	46.3	56.9
Co. Red Deer	647	467	72.7	66.6
Co. Ponoka	630	121	37.7	62.1
Co. Lac Ste. Anne	368	277	75.3	49.9
Co. Mountain View	191	107	56.0	65.3
Co. Lacombe	190	161	84.7	67.0
M.D. Foothills	82	30	37.0	56.1
M.D. Rocky View	56	43	100.0	64.0
TOTAL	7,452	4,969		

*White and Yellow areas only

THERMAL POWER GENERATION

Impact on the Land Base

Alberta is very dependent on coal for its electricity needs. In 1978, coal generated about two-thirds of the net electric energy in Alberta (ERCB 1979a: 11). In the medium-term future the proportion of Alberta's power generated by coal is likely to remain the same, but a greatly increased power demand will mean much more mining activity. The various ways in which coal mining impacts on the agricultural land base have been discussed elsewhere in this report. The facilities which are needed to generate the electricity might also use agricultural land, depending on the power plant site.

A substantial amount of land is used by power plants and by the facilities (most often cooling ponds) used to cool the water from the steam generators. Data on the Wabamun and Sundance thermal power plants in Alberta indicates that the plants occupy 940 acres of land, and the cooling ponds use 3,060 acres (data provided by the Land Reclamation Division, Alberta Environment). At any one time, the amount of land used for the power plant and cooling ponds is likely to exceed the amount of land taken up by the actual mining process. The Genesee power plant, for instance, will use about 230 acres for the power plant itself and 750 acres for cooling ponds (ERCB 1979b: 20-15, 20-17); approximately one acre of cooling pond is needed for each megawatt (MW) of power generated (ERCB 1979b: 20-15). The mining process at Genesee will require a yearly average of 764 acres to be out of agricultural use (ERCB 1979b: 21-5). Construction of 28 more 375 MW units to meet the power demands to the year 2005 (EUPC 1981: 18) will require the use of much land for power plants and cooling facilities. Based on estimates of one acre of cooling pond needed per MW of power generated, and 230 acres of land for a 750 MW generating plant, another 13,720 acres will be required to meet the power demands of the year 2005.

Very little information is available on the quality of land that has been used for power plants and cooling ponds. An estimated 2,061 acres are used by power plants alone, now in operation, or approved for operation. Nearly 1,200 acres of this total are class 1-3 lands (data obtained from the Resource Economics Branch, Alberta Agriculture).

In addition to land directly used by power plants and cooling ponds, land can be effectively lost from agricultural use if it is polluted. Sulphur, which is released into the atmosphere and subsequently oxidized, eventually falls to the ground. By making the soil more acid, the sulphur reduces soil productivity. Soil acidification resulting from the burning of coal is not thought to be a serious problem in Alberta because the Black and Brown soils in Alberta are able to neutralize much acid, and because the coals of Alberta typically have a low sulphur content. The average sulphur content of Alberta coals is less than 0.5 percent (Webber and Warne 1979: 2) whereas the coals used in Ontario average two to four percent (EUPC 1981: 47); the coals in some Alberta deposits, however, have sulphur contents approaching two percent (Stanley Associates Engineering Ltd. 1978: 2.3).

While a worry-free attitude about the soil acidification potential of sulphur released by present-day coal burning may be plausible, a worry-free attitude may not be justified in the future. Sulphur emissions due to coal burning could increase to 220,000 long tons per year

by the year 2006 (Webber and Warne 1979: 3); emissions of 220,000 long tons per year would be about six times present-day emission levels of thermal power plants. Recently, the Government of Canada issued emission guidelines based on commercially available technology capable of reducing emissions of sulphur dioxide by 90 percent (*Canada Gazette* 1981: 2849). Adoption of these guidelines by the Government of Alberta might keep sulphur emissions in the year 2006 to under 220,000 long tons, but increases in the price of electricity will be needed to pay for lower sulphur emission levels.

Ash from the power plants may also pollute nearby farmland. Ash contains trace and radioactive elements which are toxic to organisms. The toxic elements may be released into the atmosphere through the smokestack of the power plant, and may subsequently pollute nearby land when they settle out of the atmosphere. Soils near a coal-fired power plant in the northeastern United States, for example, were markedly enriched in heavy metals which were distributed in a pattern that might have been expected from examining local wind patterns (Hills and Jones 1981: 28-29). More serious than the pollution of soil due to atmospheric deposition is the potential for pollution of groundwater and surface water supplies when the ash is buried in mined-out pits, deposited in a slurry in ash lagoons, or discharged in wastewater streams (Hills and Jones 1981: 24). The tolerance levels of most living species to most heavy metals remains undetermined (Hills and Jones 1981: 28-30), and the long-term effects of metals on ecosystems are unknown (Hills and Jones 1981: 37). No immediate danger to terrestrial ecosystems near coal-fired plants has been identified (Hills and Jones 1981: 37).

Reductions in the quality of receiving waters for the waste heat from power plants are not likely to be a major problem for farmers who use the water. For example, the new Keephills (previously South Sundance) power plant is expected to increase the temperature of the North Saskatchewan River downstream from the discharge point by only a fraction of a degree Fahrenheit (ERCB 1977b: 12-6). Some reduction in water quality of receiving waters (Coleman Lake, Bullpound Creek, and Berry Creek) is expected from the effluent of the Sheerness power plant, but the impact was considered to be small because of the already low quality of waters in the area (ERCB 1979b: 12-8). Having several power plants close together, however, could create more serious water-quality problems.

In some areas, a greater issue may be the competition for water between the electricity-generating industry and agriculture. In 1976, thermal power generation was the largest user of water, and ranked second with stock watering as the second largest consumer of water, in the Battle River basin (Alberta Environment 1981b: 14). The heavy consumption of water for irrigation could complicate the construction of power plants in southern Alberta.

The use of water by thermal plants need not always have a detrimental effect on the use of water by agriculture. An attempt was made to use waste heat from the Wabamun generating station to heat a commercial-sized greenhouse. Shaw et al. (n.d.: iii) concluded that the energy recovery system that was used could not be recommended for commercial greenhouse heating, but that modifications to the test system and future changes in energy costs could alter the economics of the system. Water diverted from the Red Deer River for cooling purposes at the Sheerness plant will be injected into the Berry Creek system for irrigation,

stock watering, and other uses (Cookson and Schmidt 1980: 3). Nevertheless, the benefits to farming which result from the construction of power plants appear small in relation to the disadvantages of consumption of agricultural land, potential pollution of farm water sources, and constraints on the supply of available water which result from the construction of power plants.

Alternatives

Coal mining and subsequent generation of electricity are capable of disturbing the agricultural use of much land. For that reason alone, alternatives to thermal power generation are worth consideration. Another reason to consider alternatives is that uses of coal for other than power generation could provide more employment, income, and tax revenue than coal used for power production (Stanley Associates Engineering Ltd. 1978: 1.6, 7.11).

There appear, however, to be few alternatives to the use of coal to meet Alberta's future electricity needs. The Electric Utility Planning Council (1981) briefly considered alternatives for meeting Alberta's electricity needs from 1981 to 2005. The EUPC (1981: 2) concluded that, except for hydro, renewable resources will not significantly help meet Alberta's projected power demands. Power generated on the Peace and Slave rivers, and power imported from Manitoba along the Western Power Grid, is only expected to meet 27 percent of the extra power needed between 1981 and 2005 (EUPC 1981). Nuclear power, a non-renewable resource, was considered to be a practical option for generating electricity, but it is presently much more expensive than mine-mouth coal-fired generation (EUPC 1981: 22). Another disadvantage of nuclear power is that it requires much longer lead times for development than does thermal power (ERCB 1977b: 6-1), and creates its own environmental problems. Pricing makes oil and natural gas uncompetitive with coal for thermal generation, and Alberta Government policy limits the use of oil and gas to peak-load generation only (ERCB 1979b: 5-2; EUPC 1981: 22). Burning industrial waste will only result in the production of a small amount of electricity (EUPC 1981: 46). Economics, policy, and in the case of some renewable energy sources, a lack of technological know-how, appear to be the main stumbling blocks to the use of alternatives to coal for the production of electricity. In addition, few of the alternatives offer real land use advantages. For example, one of the reasons why Edmonton Power rejected solar, wind, and biomass alternative technologies was that these technologies had "inordinately large land requirements" (ERCB 1979a: 5-1). Greater use of oil and gas for thermal power generation might increase the amount of agricultural land used for oil and gas wells, processing plants, and so on.

There are some options that could conserve agricultural land when generating electricity with coal. The use of cooling towers rather than cooling ponds would slightly reduce the non-agricultural use of land. Low efficiencies and high costs dictate against the use of dry cooling towers (ERCB 1977b: 10-5). Also, mechanical- and natural-draft wet cooling towers would require a storage reservoir almost as large as a cooling pond, and would cost more than a cooling pond (ERCB 1977b: 10-5). For example, in 1977 it was estimated that for the Keephills thermal power plant the reservoir for a cooling tower would only require 325 fewer acres than a cooling pond — the saving in land would occur as a narrow strip around the perimeter of the water body — (ERCB 1977b: 10-19) and that the use of a mechanical-draft cooling tower would result in total investment costs $2.4 million above those for a cooling pond (ERCB 1977b: 10-5). The above figures are, however, a little deceptive because:

1) More than 325 acres might have been kept in farming by using a cooling tower. TransAlta Utilities, the proponent of the Keephills project, has a policy of purchasing land in complete quarter sections. A reduction in need by 325 acres would have meant the purchase of two or three fewer quarter sections (ERCB 1977b: 10-19).

2) The extra cost of electricity resulting from the use of a cooling tower would have been small – 0.34 percent (ERCB 1977b: 10-18).

In its decision on the Keephills thermal power plant, the ERCB approved the use of a cooling pond. The ERCB used land values in a comparison of direct costs, but did not consider losses in production and the multiplier effects thereof, if a cooling pond rather than a cooling tower were to be constructed; the ERCB's cost/benefit analysis showed that the saving of agricultural land by using a cooling tower was not cost effective (ERCB 1977b: 10-21).

The use of less electricity by consumers is another way that some conservation of agricultural land could result. The total generating capability is in excess of the amount of power used every day. The generating capacity is geared to meeting the peak demand which occurs for approximately one hour in mid-winter (EUPC 1981: 6). In addition, there is a reserve capacity, which is used to back up thermal power units in case of short-duration power outages. Minor reductions in the amount of land used for thermal power generation might be made possible by accepting a smaller reserve capacity and by introducing incentives, such as peak-hour pricing, to reduce power consumption.

Perhaps the most effective way to avoid using agricultural land for power generation is to use coal from areas with lower agricultural potential. Four mine sites in the area between Calgary and Edmonton have the potential to supply 60 percent of Alberta's new power needs between 1989 and 2005 (EUPC 1981: 33). Six mine sites north of Edmonton have the potential to supply the same amount of power (EUPC 1981: 34). Since land in northern Alberta generally has less agricultural potential than that in central Alberta, the use of six northern mines might result in less total impact on agriculture than would the use of the four central mines. The need to construct six power plant units, rather than four, and the longer distances over which power would have to be transported suggest, however, that the cost of electricity using the northern sites might be higher than if the central sites were used.

NATURAL GAS PROCESSING AND MANUFACTURING INDUSTRIES

Impact on the Land Base

The Energy Resources Conservation Board must process the applications of all major industries which use the hydrocarbon resources of Alberta for fuel or feedstock (Oil and Gas Conservation Act, RSA 1980, cO-5 s30(2, 3)), and must ensure that the oil, gas, and crude bitumen resources of Alberta are conserved (Oil and Gas Conservation Act, RSA 1980, cO-5 s30(6); Energy Resources Conservation Act, RSA 1980, cE-11 s2(c)). Recommendations of the ERCB are passed on to the provincial Cabinet which makes the final decision on the application. Approvals for large hydrocarbon-consuming industries have, to date, resulted in the industrial use of much land.

The amount of land that has been taken out of agricultural production is difficult to determine because careful records of the conversion of agricultural land to industrial uses have not been maintained. Information from the ERCB suggests that the leases for the approximately 400 natural gas processing plants operating in Alberta affect about 35,000 acres; the processing plants are built on about 3,500 of the 35,000 acres of land. About 70 percent of the natural gas plants are in areas suitable for agriculture. Another 25,000 acres of largely agricultural land are being used for the plant sites and buffer zones of approximately 40 industries which use petroleum hydrocarbons as fuel or feedstock. Not all the land which is held, however, is taken out of agricultural production. About one-half of the land may be farmed by the previous landowner or by a contract farmer, or by the company as a means of monitoring air pollution.

The quality of agricultural land used by petroleum-related industries is not well documented in ERCB files. Information obtained from some other sources, however, does provide some insight into the quality of land used by petroleum-related industries. Birch (1982: 67) estimated that 356 acres of agricultural land were used for gas plant sites, not including the rest of the lease, from 1976 to 1980; 137 acres (38.5 percent of the total) were class 1-3 soils. The quality of land used by industry has recently been a matter of public concern near Joffre, located northeast of Red Deer, Alberta. There was considerable opposition to the Nova/Shell application to build a plant to manufacture ethylene and polyethylene from natural gas, and to the Union Carbide application to build a plant which would manufacture ethylene glycol from ethylene. The Nova/Shell plant site could be expected to occupy 240 acres of land – 56 acres of class 2 land, 120 acres of class 3 land, and 64 acres of class 4 land (Currie 1981: 4). The Nova/Shell plant would be located very close to three other plants which manufacture ethylene. The Union Carbide plant would be about five miles from the Nova/Shell site, and could be expected to occupy between 250 and 290 acres of land. About 46 percent of the land for the plant site would be class 2 and 3 (Currie 1981: 2). In both cases, the buffer zones would affect more land than the plant site. Both applications were subsequently approved by the ERCB and the Government of Alberta. It is possible that most of the 25,000 acres of land affected by industries using hydrocarbons as fuel or feedstock are of similar agricultural capability, since many of these industries are also located in the Edmonton-Calgary corridor.

There are several possible reasons why industrial plants continue to be sited on good agricultural land. Some simplified reasons and counter-arguments are:

1) Construction costs are cheaper on good agricultural land. The displacement of agriculture to poorer quality land, however, increases the cost of farming. Unfortunately, the extra costs of farming on poorer quality land are recurring costs. A more appropriate stategy might be to locate industry on less productive land. The cost of locating industry there would be high, but it would be a one-time cost and industry would probably be more able than agriculture to carry the higher costs because of the higher value of its produce.

2) Cost/benefit (C/B) analysis favors the construction of petrochemical plants. For example, in its approval of the Nova/Shell polyethylene plant, the ERCB (1981e: 13) believed that the amount of good-quality land to be affected by

the plant would be "modest in relation to the public benefit that would be obtained", and so considered the plant site to be an acceptable one. Agriculture cannot offer to society the immediate and large benefits that industries can. Although there may be argument about whether or not the true value of agriculture was included in C/B analyses, the bottom line of counter-arguments is that food production is not possible on land occupied by manufacturing plants.

3) Ironically, it may sometimes be necessary to use good agricultural land for industry in order to conserve arable soils for agriculture. Conservation of agricultural land was one of the reasons why the ERCB did not reject the site chosen for the Nova/Shell polyethylene plant. The site chosen already had utilities and an infrastructure which would otherwise have to be duplicated on a *greenfield* site. The impact on agriculture, however, might be greater only if the greenfield site were of equal productivity to the site chosen. Siting industry on poorer agricultural land in the first place would avoid having to use good agricultural land in order to save it elsewhere. Local governments are responsible for land use zoning.

The ERCB (1981e: 13) has expressed the points of view that good agricultural soils should not be allocated to industry and to urban-related developments, and that the amount of expansion at any one site should be limited. The ERCB can rule out a site for a plant when the site is technically, economically, or environmentally unfeasible, and the Board could express reservations about a site in its decision which is passed on to Cabinet. Siting industry on agricultural land is, however, an environmental issue that is larger and less clear-cut than those the Board normally handles, for example, the technical and economic feasibility of using certain industrial processing techniques to meet the province's air- and water-quality standards, and it is an environmental issue over which the Board has no clear jurisdiction. Continued displacement of agriculture by petroleum-related industries seems likely unless some re-ordering of values about the industrial and agricultural uses of good-quality agricultural land occurs.

Biological and Other Effects

The plants which process and consume hydrocarbons affect agricultural land in more ways than directly consuming land. Accommodation for plant employees also results in non-agricultural use of land; one of the intervenors at the hearings for a third ethylene plant located near Red Deer estimated that for every 150 people employed at such plants, 160 acres of land would be dedicated for urban purposes, not including infrastructure (ERCB 1981b: 9). Some effects on the land base are more subtle. For instance, the property value of land near the industrial sites may increase due to speculation. The higher property values may reduce the economic viability of farming because new farmers may not be able to afford to buy land from farmers wishing to sell their land. Farmers with land close to industrial sites may feel that their land will be acquired when the industries expand, and may therefore curb their investment in the farm. Recently, there has been much concern over the effect that sulphur emitted from gas-processing and petrochemical industries has on farming.

Approximately one-half of the natural gas already found in Alberta has significant amounts of hydrogen sulphide (Webber and Warne 1979: 3). In order to produce a marketable gas, most of the hydrogen sulphide must be removed. The percent of the hydrogen sulphide that must subsequently be recovered as elemental sulphur varies with the sulphur inlet rate of the gas plant. For example, if the sulphur inlet rate of a gas-processing plant constructed after December 1, 1980 is 10 tons per day, then 94.5 percent of the sulphur must be removed; if the sulphur inlet rate is equal to or greater than 2,500 tons per day, 99 percent of the sulphur must be removed (ERCB 1980e). The hydrogen sulphide which is not recovered is burned.

Burning of hydrogen sulphide results in the formation of chemical compounds which may be harmful to agriculture. When hydrogen sulphide is burned, one of the chemical compounds formed is sulphur dioxide. Sulphur dioxide may undergo further chemical reaction to form sulphite which, in turn, may be converted into sulphuric acid. The chemical changes may occur in the atmosphere, or in soil which has adsorbed sulphur.

Very little of the sulphur falls to the ground as acid rain, partly because of the fairly low frequency of rainfalls in Alberta and because rainfall is a poor scavenger of sulphur dioxide at ambient concentrations. Rainwater of pH 3, however, has been recorded in Alberta (McCulloch 1979: 122). A pH level of 3 would be beyond the normal variations that one could expect in rainwater. Sulphur that falls in precipitation is a small fraction of that deposited directly on the soil, or adsorbed by surface water or vegetation (Sandhu et al. 1980: 26; Hocking and Nyborg 1974: 71).

Sulphur released into the environment may harmfully affect agriculture by reducing the fertility of agricultural land. Sulphur has a tendency to make soils more acid and less fertile. Under acid conditions, the solubility of desirable plant nutrients such as phosphorus decreases, and the plant availability of toxic metals such as aluminum increases. Sulphite appears to inhibit the ability of soil micro-organisms to reproduce (McCready 1979: 117-118). If this is the case, there would be less breakdown of soil organic matter, and a reduction in the ability of micro-organisms to enrich the soil by fixing nitrogen from the atmosphere (McCready 1979). In controlled experiments, aqueous sulphite concentrations which would result from 0.08 parts per million of sulphur dioxide in the atmosphere reduced the rate of reproduction of soil micro-organisms by 60 to 86 percent (McCready 1979: 116). This atmospheric concentration of sulphur dioxide is higher than that normally experienced in Alberta. For example, although the maximum one-hour sulphur dioxide reading in the Pincher Creek area in February, 1981 was 0.05 ppm, the 24-hour maximum reading was 0.01 ppm, and the arithmetic mean concentration was 0.00 ppm (Alberta Environment 1981a: 6). The problem of soil acidification has received more attention than has the potential problem of reductions in the ability of soil micro-organisms to reproduce.

The potential for harm to agriculture due to soil acidification is greatest on soils that are naturally acid – generally, the Grey Wooded soils which are found mostly in northern Alberta. Western Research and Development (1978: 4), estimated that approximately 42 percent of the cultivated soils of Alberta are susceptible to acidification. Some acidification of Alberta soils may already have occurred. Hocking and Nyborg (1974: 72) noted a decrease in soil pH of 0.05 - 0.10 pH units near a gas treatment plant over a period of three to ten months. Nyborg et al. (1975: 73) detected a decrease in soil pH in excess of 0.15 pH units

downwind of gas plants in the Calgary-Olds area. The area in which the decrease was noted covered 10,000 square miles. Hoyt et al. (1981: 57) estimated that within 15 years another 118,650 acres could become acid (pH less than or equal to 6.0) due to industrialization.

Small decreases in soil pH can have a substantial effect on plant productivity. The effect depends upon the crop grown and upon the pH of the soil. A decrease in pH by 0.1 units in the soil pH range 5.2 to 5.5 would decrease the yield of barley by 143 pounds per acre (three bushels per acre) (Western Research and Development 1978: 4); a similar decrease in the soil pH range 5.5 to 6.0 would decrease the yield of alfalfa by 400 to 500 pounds per acre (Western Research and Development 1978: 4). As soils become more acid, the range of crops that can be grown on them decreases.

There is some uncertainty about how long it takes for sulphur emissions from natural gas processing plants to have a noticeable effect on surrounding soils. Western Research and Development (1978: 28) estimated that the deposition of sulphur on soils near gas plants should not exceed 5.4 pounds/acre/year; at a deposition rate of 5.4 pounds/acre/year, the soil pH might be expected to decrease by 0.1 unit after 15 to 20 years. Hocking and Nyborg (1974: 72-73) estimated that soils near gas plants could experience decreases in soil pH of 1.5 units after 10 or 15 years. One of the reasons why predictions such as those above cannot be generalized is that there has been considerable variation in the estimates of sulphur deposition near industrial sources. Another is that the calcium levels in Alberta soils vary a great deal; soils with more calcium are better buffered against increases in soil acidity than soils with little calcium. Also, not all of the sulphur deposited on the soil remains to deleteriously affect the soil. Leaching is an important process in preventing the build-up of sulphur compounds in soils around gas plants (Shipley 1975: 87). Some of the sulphur is converted to insoluble organic forms which are stored in the soil without altering the soil chemical reaction (Shipley 1975: 91; McCulloch 1979: 122). When the organic sulphur is released and what the resultant effect is on the soil are questions for which there are yet no clear answers (McCulloch 1979: 123).

The release of sulphur from gas-processing plants need not always have a harmful effect on a soil's chemical properties. For soils that are naturally sulphur deficient, the inadvertent addition of some sulphur would be beneficial (MacDonald and Klemm 1973: 11; Dick and Walker 1975: 83) because sulphur is an essential plant nutrient. The benefits of inadvertent additions of sulphur are, however, minimal because deposition on nearby soils varies with the season (Nyborg and Walker 1977: 174), because most of the deposition occurs on soils which have a sufficient supply of sulphur (Nyborg and Walker 1977: 176), and because only a small amount of the sulphur gained by the soils is immediately available for plant use (Nyborg and Walker 1977: 188, 192).

Sulphur released into the environment may reduce the viability of vegetation. Sulphur dioxide can enter leaves through the stomata. After entering the leaf, sulphur dioxide is oxidized to form sulphite and sulphate. Sulphite strongly inhibits photosynthesis (Amundson et al. 1975: 107). Plant tissue is also damaged by long-term exposure to sulphate (Amundson et al. 1975: 107). Conditions which favor stomatal opening – "high relative humidity and soil moisture, with moderate light intensity and temperature above $5^{o}C$ ($41^{o}F$)" (Amundson et al. 1975: 107) – result in the greatest damage to plants. Plants vary in their susceptibility to

sulphur dioxide. Cereal crops, sugar beets, and corn respectively show very low, intermediate, and high tolerance to sulphur dioxide (McCready 1979: 119). Sulphur dioxide concentrations in the ambient air would have to exceed Alberta's air-quality standards before injury to pollution-sensitive plants would occur, except possibly for the 24-hour standard (Table 12). The levels resulting in plant injury, however, are for sulphur dioxide as a single pollutant. The effect of sulphur dioxide as a pollutant may be greater if other air pollutants are also present (Mudd 1975: 12).

Sulphur emissions may detrimentally affect farm animals. Inhalation of heavy concentrations of sulphur dioxide can damage the respiratory systems of animals. A link between ingestion of vegetation growing on soils in an emission zone and white muscle disease and hormonal disruption, which results in changes in the metabolism and reproductive trends of farm animals, has been hypothesized. According to the hypothesis, white muscle disease would result from deficiencies of selenium; selenium uptake by plants would be depressed when sulphur concentrations in the soil are high.

Nevertheless, in one study, gas-plant emissions showed no statistically significant effects on the respiratory tracts, productivity, fertility, and disease rates of cattle, hogs, and chickens (McCulloch 1979: 128). Although the extent and severity of white muscle disease in Alberta remains uncertain, McDonald and Klemm (1973) noted that there appears to be some correlation between reduced selenium levels in vegetation and soil types such as Grey Wooded soils, and that without selenium supplements the livestock industry in central Alberta would be in serious jeopardy. The ERCB (1982b: 3-8), however, believes that there is insufficient evidence of a casual relationship between sour-gas emissions and white muscle disease, and that immediate policy changes are not warranted. The Board (1982b: 3-7), however, does believe that more thorough research into the relationship between sulphur dioxide emissions and selenium-related diseases is urgently needed. Concern about the effects of sulphur emissions on human health would also be warranted if some effects of sulphur emissions on the health of farm animals were demonstrated.

Table 12. Comparison of sulphur dioxide levels causing injury to pollution-sensitive plants and Alberta's air-quality standards for sulphur dioxide

Duration of Pollution Episode	Ambient Air Sulphur Dioxide Concentrations (ppm) Injurious to Pollution-Sensitive Plants		Alberta's Clean Air Regulations* for Sulphur Dioxide (ppm)
	Column 1	Column 2	
0.5 hr	1 - 4	1 - 4	0.20
1.0 hr	not given	0.50 - 2.5	0.17
8.0 hr	0.05 - 0.5	0.10 - 0.75	no 8 hr standard
24.0 hr	not given	not given	0.06

*The standards given are for the maximum level of pollutant allowed

Sources: Column 1 - Mudd 1975:11-12; Column 2 - Heck and Brandt 1980:200

Some Prospects for Reducing the Biological Effects

Present-day uncertainties about the impacts of sulphur emissions on soil, plants, and animals are overshadowed by the expected increases in sulphur emissions from gas processing, coal, and oil sands plants, as well as other facilities. Based on an extrapolation of sulphur emission trends from 1956 to 1978, and some assumptions about the contribution to the pollutant load by some industrial sectors (Webber and Warne 1979: 9-10), by the year 2006 annual sulphur emissions could be twice the 1978 level of 281,000 long tons; cumulative emissions could be near 19 million long tons; that is, three or four times the present-day cumulative amount (Webber and Warne 1979: 11). Very severe environmental problems resulting from sulphur emissions could be apparent within 25 years, unless sulphur emissions are held in check.

Further restraint of sulphur emissions may be difficult since alternative techniques for reducing emissions may not be environmentally or technically feasible. For example, in one application to construct a gas-processing plant brought before the ERCB, two alternatives to acid gas emissions were identified:

1) injection of incinerator gas into underground rock formations, and

2) flue gas desulphurization using limestone, in which the sour gas is absorbed into a slurry of limestone.

But there are environmental trade-offs associated with these alternatives. For instance, the proponent argued that the compressors needed to inject incinerator gas underground would consume much fuel, and would emit much nitrogen oxide (ERCB 1981f: 15). The major environmental problems associated with the flue gas desulphurization process are those relating to quarrying of the limestone and disposing of the spent material. Also, at this time, the technological feasibility of this flue gas desulphurization process has not been demonstrated.

Until feasible methods of further controlling sulphur emissions are found, attacking the symptoms of sulphur dioxide pollution may be a reasonable strategy. Applying limestone to the soil would ameliorate some of the effects of sulphur. Where the acidity of soil was not less than pH 3.5 to 4.0, where acidity extended no deeper than six inches, and where soils were low in elemental sulphur, not more than 10 to 15 tons of limestone per acre should be required to reclaim the soil (Nyborg 1974: 66). Farmers can be subsidized for 80 percent of transportation costs in excess of $5.00 per ton through Alberta Agriculture's Lime Freight Assistance Program; this subsidy represents about 30 percent of the average cost of lime applications – $33.00 to $44.00 per ton (Hoyt et al. 1981: 63). Additional problems are, however, encountered if heavy doses of lime are needed. For instance, a thick lime layer near the soil surfaces is a poor medium for seed germination, and at heavy lime application rates, other essential nutrients such as nitrogen and phosphorous may become deficient (Nyborg 1974: 60, 63). Though feasible, applying limestone in order to rectify soil acidity caused by sulphur emissions would increase the cost and complexity of farming.

The ERCB (1982b) recognizes that sulphur emissions from gas-processing plants could have far-reaching and serious consequences for agriculture in Alberta. The Board, however, feels that

changes in the policies on sulphur emissions are not generally warranted at this time. Among the many reasons cited for this conclusion are lack of conclusive evidence that emitted sulphur is responsible for serious environmental damage in Alberta (ERCB 1982b: 3-7) and the high costs of further sulphur extraction (ERCB 1982b: 5-8). The Board (1982b: 3-4, 3-7) recommended that there be further studies on the environmental effects of sulphur emissions in Alberta to provide better information upon which to decide whether policy changes are needed.

The information about sulphur emissions and their control is changing rapidly. For example, an air pollution control conference held in Edmonton, Alberta on October 1, 1982 provided considerable information on approaches and technologies for reducing sulphur dioxide emissions by the year 2000.

Treatment of sulphur dioxide emissions alone would be an incomplete approach to solving the environmental problems for farming presented by natural gas plants and manufacturing industries. These industries generate other pollutants too. Sulphur that is extracted from gas (or oil), and which is not incinerated, is stored near the processing plants for later industrial use. The damage to nearby soils which are affected by windblown sulphur is severe – "soils are barren, very acid (pH 2 to 4), prone to wind and water erosion, and they make runoff water extremely acid" (Nyborg 1974: 55). On such soils, between 100 and 300 tons of limestone per acre may be required to reclaim the soil (Nyborg 1974: 57, 70). Fortunately, only about a thousand acres in Alberta have been damaged by sulphur dust (Nyborg 1974: 55). Ozone, which is a strong oxidizer capable of harming plants, is generated for some distances in the plumes downwind from sour-gas plants. Nitrogen oxides, like sulphur oxides, can be converted into acids, and are a major source of air pollution in Alberta. In 1978, the estimated nitrogen dioxide emissions resulting from fuel combustion for the compressors, heaters, and boilers of gas-processing plants were 132,133 long tons (Peters and Sandhu 1980: 7), 43 percent of the level of the observed sulphur dioxide emissions from gas-extraction plants (Sandhu 1979: 19). Nitrogen oxides are expected to be the main air contaminants from petrochemical plants. Generation of other pollutants, such as those mentioned above, necessitates a multi-faceted approach to solving the ecological problems created for agriculture by gas-processing and manufacturing industries.

SYNOPSIS

There are many ways that linear developments, resource extraction, and industry negatively affect the agricultural land base. Discussions within this report have focussed on three main types of impact:

1) Non-agricultural use of land which is capable of supporting agriculture. Of particular concern is the use of highly productive soils for roads, industry, and so on. The highly productive soils tend to be concentrated in the Edmonton-Calgary corridor of Alberta. In cases of strip mining, and oil and gas well activity, the land is expected to be only temporarily lost from agriculture. There are, however, concerns about our ability to fully reclaim land that has been severely disturbed.

2) Reduction in the productivity of land due to changes in the physical and chemical properties of the soil. These changes result from oil and salt water spills, but there is more popular concern about the potential of sulphur dioxide emissions from sour gas plants and thermal power plants to make soils more acid. The Grey Wooded soils of Alberta are more easily acidified than are the Black and Brown soils. The Grey Wooded soils can little afford acidification, for the costs of farming on Grey Wooded soils are already higher than they are on Black and Brown soils.

3) Increases in the cost of farming. Farming around obstacles such as transmission towers and oil wells increases the amount of time needed by farmers to work cultivated fields and decreases productivity in areas where field operations overlap. Fragmentation of cultivated fields by roads similarly increases the cost of farming. Increases in the cost of farming require higher prices for agricultural commodities in order to make farming economically feasible.

The total provincial impact of linear developments, resource extraction, and industry on the agricultural land base is not known, but it is undoubtedly large and is expected to increase in the future. Table 13 provides a very brief description of the nature and extent of the major disturbances discussed in this report, and provides brief, general predictions for each of the disturbances. In only a few instances have benefits to the agricultural land base resulting from linear developments and industry been identified.

There have been recent Alberta Government efforts to reduce the impact of linear developments, resource extraction, and industry on agriculture. The government's adoption of a coal development policy, a policy respecting the location of major transmission lines, and corner locations for oil wells are examples of these efforts. Other Government of Alberta activities seem more likely to aggravate, rather than reduce, conflict between urban/industrial interests and agriculture. The government's policies of diversification of the Alberta economy and decentralization have been more concerned with the distribution of industrial benefits than with their impacts on the agricultural land base. The work of some government departments, for example, Alberta Transportation and departments which promote economic development, results in the use of farmland for non-agricultural purposes. This might be expected since it is not the mandate of government departments such as Alberta Transportation to protect the agricultural land base; rather it is the mandate of government departments to fulfil their legislated responsibilities.

Table 13. Overview of disturbance to the agricultural land base in Alberta

Type of Disturbance	Current Extent of Disturbance	Trend
1. Power Transmission Lines	96,827 linear miles; a maximum of 4,336 acres removed from agricultural production by power line structures; costs for farming around towers.	Greater due to increased power demands, but at a slower rate due to the use of 500 kV lines, corridors, etc.
2. Roads	92,650 linear miles; 870,000 acres of land occupied.	More land consumed by roads, especially in agricultural fringe areas; land used at a rate of 5,000 acres per year.
3. Pipelines	112,000 linear miles; spills affect about 300 acres per year.	Some increase. More than 300 acres per year affected by spills. Reclamation of spill-affected areas.
4. Coal Mining	7,775 acres disturbed by mining operations.	Due to use of coal for power generation, many more acres will be disturbed, not all "permanently." Reclamation potential of disturbed lands is not known.
5. Oil and Natural Gas Exploration and Extraction	204,800 acres disturbed; 69,120 acres disturbed and reclaimed.	A continuation of the 1976-1981 trend would see nearly 20,000 acres disturbed each year. Development of oil sands might reduce drilling activity.
	Substantial costs for farming around wells.	Adoption of northeast corner target areas should reduce economic impact on farming in new oil lease areas.
6. Industrial Parks	Total size of industrial parks with land available for occupancy, 47,500 acres.	Increases in land dedicated to industrial parks can be expected, especially if oil sands are developed.
7. Thermal Power Generation	4,000 acres.	By the year 2005, another 13,720 acres will be used for power generation sites.
	Some soil pollution by sulphur and coal ash.	Some increase, but adoption of stricter pollution guidelines will mitigate soil pollution.
8. Natural Gas Processing Plants	Leases affect 35,000 acres. Plants occupy 3,500 acres.	Some increase in affected acreage.
	In most cases, sulphur emissions negatively affect soil productivity.	Increase.
9. Other Petroleum-Related Industries	25,000 acres.	Increase.

As long as government and industry alike meet public demand for cheap goods and services, there is little incentive for the public to curb its demands. Reduction in public demand for the goods and services is, however, one way that conservation of agricultural land could be effected. The reduction in demand might require only simple life style changes, such as greater reliance on public transportation. Paying higher costs for goods and services is another way that conservation of farmland could result without radical alteration of life styles. For example, higher prices for electricity might allow power companies to use transmission towers that take less land out of agricultural production than do towers which are now commonly used. The public can voluntarily reduce its non-agricultural use of farmland, but people are not likely to curb their consumptive habits unless they feel that everyone will do the same. If this is true, then government leadership in the implementation of a conservation ethic through education, example, pricing, or legislation would be required.

GLOSSARY

Corona

Corona is the breakdown of air in the near vicinity of a transmission line when the electric field at the conductor surface exceeds the dielectric strength of air (Miller and Kaufman 1978: 8). Corona is an effect which occurs mostly in foul weather.

Electromagnetic Induction

Electromagnetic induction is the collection of an electric charge in an object when the "conduction object, either alone or in conjunction with the earth, provides a conducting loop in the magnetic field surrounding the transmission line" (Wacker 1977: 16). Transmission line voltage has no effect on the magnitude of electromagnetically induced currents (Wacker 1977: 28).

Electrostatic Induction

Electrostatic induction is the collection of an electric charge in an ungrounded object placed in the electric field that exists between a transmission line and the ground. When a person who is grounded touches the ungrounded object, a large portion of the collected charge will flow through the person.

Greenfield

A greenfield site is one which is not already used for industrial purposes, and which is separated from other industrial developments.

Mercaptans

Organic sulphur compounds that are derivatives of hydrogen sulphide.

Parts Per Million (ppm)

The weight units of solute per million weight units of solution.

Piping

The erosion process of surface water working down through the cracks in the soil surface and carrying surface soil with it.

REFERENCES

Alberta Energy and Natural Resources. 1976. *A Coal Development Policy for Alberta.* Alberta Department of Energy and Natural Resources. 38 pages.

Alberta Environment. 1977. *Guidelines for the Reclamation of Land in Alberta.* Land Conservation and Reclamation Council, Alberta Department of the Environment and Alberta Department of Energy and Natural Resources. 3 pages plus appendices.

----- 1978. *Edmonton Regional Utility Study.* Pollution Control Division, Alberta Department of the Environment. 21 pages.

----- 1980. *Hydrogeologic Effects of Coal Strip Mining at the Whitewood Mine.* Alberta Department of the Environment. 174 pages.

----- 1981a. *Ambient Air Quality Survey Pincher Creek Area January 1 to March 24, 1981.* Alberta Department of the Environment. 17 pages.

----- 1981b. *Battle River Basin Study Planning Report.* Alberta Department of the Environment. 56 pages.

Alberta Hansard. November 5, 1981, page 1477.

Alberta Municipal Affairs. 1978. *Regional Policies on the Conversion of Agricultural Land to Other Uses.* Alberta Department of Municipal Affairs. 7 pages.

Alberta Planning Board. 1981. "Rural Industrial Land Use. Some Policy Guidelines for the 1980's." Alberta Department of Municipal Affairs. 7 pages.

Alberta Tourism and Small Business. 1981. *Assisting Regional Communities Industry and Business 1981 Program.* Alberta Department of Tourism and Small Business. 39 pages.

Alberta Utilities and Telephones. 1981. "A Statement of Policy Respecting the Location and Approval Procedures for Major Electric Transmission Lines." Alberta Department of Utilities and Telephones. 6 pages.

Amundson, R.G., A.H. Legge, and R.B. Walker. 1975. "Field Studies of Photosynthesis in Pine, Spruce and Aspen Periodically Subjected to SO_2 and H_2O From a Nearby Source." In *Proceedings of Alberta Sulphur Gas Research Workshop II,* pages 106-121. Alberta Department of the Environment and the University of Calgary. Edmonton: The Queen's Printer. 174 pages.

Birch, A. 1982. *An Inventory of Changes in Alberta's Agricultural Land Base Between 1976 and 1980.* RE-03-13-82. Alberta Department of Agriculture. 90 pages.

Blauel, R. and D. Hocking. 1974. "Problems of Chloride and Heavy Metal Contamination." In *Proceedings of a Workshop on Reclamation of Disturbed Lands in Alberta,* page 19. Information Report Nor-X-116, Northern Forest Research Centre, Edmonton. 216 pages.

The Canada Gazette 18(115): 2849-2853. Part I, May 2, 1981. "Thermal Power Generation Emissions – Natural Guidelines for New Stationary Sources." Ottawa: The Queen's Printer for Canada.

Carvallo, H.O., G.W. Gee, and A. Bauer. 1979. "Analysis of Water Accumulation and Storage in Strip Mined Soils of Western North Dakota." In *Proceedings Canadian Land Reclamation Association Fourth Annual Meeting,* pages 157-172. Canadian Land Reclamation Association, Guelph. 283 pages.

Cookson, J.W., and D. Schmidt. 1980. "Water Resources and Irrigation Development in Southern Alberta." Government of Alberta Ministerial Statement.

Currie, C. 1981. "Results of Energy Resources Conservation Board Hearings Held April 1981 at the Capri Centre in Red Deer." Notes for a May 19, 1981 meeting of the Red Deer Regional Planning Commission.

deJong, E. 1979. "Reclamation Problems in the Oil Industry." In *Proceedings Canadian Land Reclamation Association Fourth Annual Meeting,* pages 39-52. Canadian Land Reclamation Association, Guelph. 283 pages.

----- 1980. "Reclamation Problems and Procedures for the Oil Industry on the Canadian Prairies." *Reclamation Review* 3(2): 75-85.

DeLeuw Cather Consulting Engineers and Planners and L.W. Downey Research Associates Ltd. 1974. *A Multi-Disciplinary Evaluation of the Calgary Parkway Ring.* Alberta Department of Highways and Transport. 77 pages.

Dick, A.D. and D.R. Walker. 1975. "Adsorption of Atmospheric Sulphur Gases by Bare Soils." In *Proceedings of Alberta Sulphur Gas Research Workshop II,* pages 77-83. Alberta Department of the Environment and the University of Calgary. Edmonton: The Queen's Printer. 174 pages.

Edmonton Regional Planning Commission (ERPC). 1976. *Transportation and Urban Growth.* Draft Discussion Paper 12. Edmonton Regional Planning Commission, Edmonton. 48 pages.

Electric Utility Planning Council (EUPC). 1981. *Power Generation in Alberta (1981-2005).* Electric Utility Planning Council, Edmonton. 48 pages.

Energy Resources Conservation Board (ERCB). 1974. "Impact of Petroleum Activities in Irrigation Areas." Decision 74-5, Application No. 7625, Energy Resources Conservation Board, Calgary. 20 pages.

----- 1975. "Sump Fluid Disposal Requirements." Attachments. Interim Directive No. ID-OG 75-2, Energy Resources Conservation Board, Calgary. 6 pages.

----- 1977a. "Alberta's Oil and Gas Well Spacing and Target Area Regulations. Background Information." A submission prepared for Proceeding 9750 held April 19, 1977 in Edmonton, Alberta. Energy Resources Conservation Board, Calgary. 11 pages.

----- 1977b. *In the Matter of Applications by Calgary Power Ltd. for the Extension of the Highvale Mine and the Construction and Operation of a Proposed South Sundance Thermal Power Plant.* ERCB-AE Report 77-AA. Energy Resources Conservation Board, Calgary and Alberta Department of the Environment. Various pagination.

----- 1977c. *In the Matter of a 240 kV Transmission Line Proposed by Calgary Power Ltd. Between Calgary and Lethbridge.* ERCB Report 77-G, Energy Resources Conservation Board, Calgary. Various pagination.

----- 1978. "Spacing and Target Area Requirements for Oil and Gas Wells Drilled in the Province of Alberta." Decision 78-5, Application No. 9750 X, Energy Resources Conservation Board, Calgary. 24 pages.

----- 1979a. *In the Matter of Application by Alberta Power Limited, Forestburg Collieries Limited and Manalta Coal Ltd. for the Development of the Sheerness Mine and the Construction and Operation of a Proposed Sheerness Thermal Power Plant and In the Matter of Applications by Edmonton Power for the Proposed Genesee Thermal Power Plant.* ERCB-AE Report 79-AA, Energy Resources Conservation Board, Calgary and Alberta Department of the Environment. Various pagination.

----- 1979b. *Minimum Distance Requirements Separating New Sour Gas Facilities From Residential and Other Developments.* Appendices I and II. Interim Directive No. ID 79-2, Energy Resources Conservation Board, Calgary. 5 pages.

----- 1980a. *Conservation in Alberta.* ERCB Report 80-36, Energy Resources Conservation Board, Calgary. 26 pages.

----- 1980b. "Drilling Spacing Unit Target Area Requirements for Oil and Gas Wells Drilled in the Grande Prairie Area." Decision 80-8, Application 800050, Energy Resources Conservation Board, Calgary. 8 pages.

----- 1980c. *500 kV Transmission Lines Keephills-Ellerslie.* Report 80 A, Energy Resources Conservation Board, Calgary. Various pagination.

----- 1980d. *Reserves of Coal Province of Alberta at 31 December 1979.* ERCB 80-31, Energy Resources Conservation Board, Calgary. Various pagination.

----- 1980e. "Sulphur Recovery Guidelines Gas Processing Operations." Informational Letter IL 80-24, Energy Resources Conservation Board, Calgary, and Alberta Department of the Environment. 3 pages.

----- 1981a. *1981 Alberta Coal Industry Annual Statistics.* ERCB 81-29, Energy Resources Conservation Board, Calgary. 35 pages.

----- 1981b. "The Alberta Gas Ethylene Company Ltd. Industrial Development Permit to Manufacture Ethylene." Decision 81-10, Application 800853, Energy Resources Conservation Board, Calgary. 16 pages.

----- 1981c. "Dome – Lindbergh Well Spacing." Interim Decision, Application 801010, Proceeding 810132, Energy Resources Conservation Board, Calgary. 3 pages.

----- 1981d. "Drilling Spacing Unit Target Area Requirements for Oil and Gas Wells Drilled in the Province of Alberta." Decision 81-20, Proceeding 810078, Energy Resources Conservation Board, Calgary. 22 pages.

----- 1981e. "Nova, An Alberta Corporation and Shell Canada Limited Industrial Development Permit to Manufacture Polyethylene." Decision 81-16, Application 800910, Energy Resources Conservation Board, Calgary. 17 pages.

----- 1981f. "Phillips Petroleum Company Western Hemisphere Gas Processing Plant Morley-Ghost River Area." Decision 81-12, Application 801022, Energy Resources Conservation Board, Calgary. 25 pages.

----- 1982a. "Alberta Electric Industry Annual Statistics 1981." ERCB 82-28, Energy Resources Conservation Board, Calgary. 31 pages.

----- 1982b. "Sour Gas Processing in Alberta." ERCB 82-D, Energy Resources Conservation Board, Calgary. Various pagination.

Goettel, A.W. 1977. "A Perspective of Resource Development on Agricultural Land." In *Proceedings of 1977 Annual Alberta Soil Science Workshop on Soil Conservation, Reclamation and Research,* pages 93-107. Alberta Soil Science Workshop, Edmonton. 212 pages.

Hanus, F. 1979. *Assessment of Effects of Power Lines on Farming Operations in Alberta. A Summary.* Alberta Department of Agriculture. 19 pages.

----- 1980a. *Issues of Single Use and Multiple Use Corridors.* Information Bulletin 80-3-1, Alberta Department of Agriculture. 16 pages.

----- 1980b. *An Overview of Compensation for Well Site Leases in Alberta.* Information Bulletin RE-10-04-80, Alberta Department of Agriculture. 57 pages.

----- 1981. *Assessment of Impacts of Increased Number of Well Sites Per Unit of Land on Farming Activities.* Information Bulletin RE-05-20-81, Alberta Department of Agriculture. 35 pages.

Harrington, D.C. 1979. "Implementation of Reclamation Legislation in Alberta." In *Proceedings Canadian Land Reclamation Association Fourth Annual Meeting,* pages 257-269. Canadian Land Reclamation Association, Guelph. 283 pages.

----- 1981. "Type of Resource Development Affecting Agricultural Land." Paper read at Annual Meeting of Alberta Institute of Agrologists in Calgary, Alberta.

Heck, W.W. and C.S. Brandt. 1977. "Effects on Vegetation: Native, Crops, Forests." In "The Effects of Air Pollution," *Air Pollution,* Vol. III, A.C. Stern, ed., 3rd edition, pages 157-229. New York: Academic Press. 684 pages.

Hills, L.V. and W. Jones. 1981. *Trace Elements in Coal.* Edmonton: Environment Council of Alberta. 111 pages.

Hocking, D. and M. Nyborg. 1974. "The Problem of Soil Acidification by Sulphur Dioxide." In *Proceedings of a Workshop on Reclamation of Disturbed Lands in Alberta,* pages 71-75. Information Report Nor-X-116, Northern Forest Research Centre, Edmonton. 216 pages.

Homeniuk, T.F. 1980. "Utility Corridors." Paper read at July 8, 1980 meeting of the Non-Renewable Resources Study Group of the Public Advisory Committee to the Environment Council of Alberta in Edmonton, Alberta.

Hoyt, P.B., M. Nyborg, and H. Ukrainetz. 1981. "Degradation by Acidification." In *Agricultural Land. Our Disappearing Heritage – A Symposium. Proceedings of the 18th Annual Alberta Soil Science Workshop,* pages 41-71. Alberta Soil and Feed Testing Laboratory, Edmonton. 544 pages.

Inkis, W.V. 1977. "Demonstrations to Public of EHV Transmission Line Effects." Paper read at the Institute of Electrical and Electronics Engineers Power Engineering Society Summer Meeting in Mexico City, Mexico.

Ironside, R.G. and W.W. McVey Jr. n.d. *Migration, Place Preferences and Decentralization Policy in Alberta.* Alberta Department of Advanced Education and Manpower. 34 pages.

Keller, W.E. 1979. "DC Superconducting Cables." In *Workshop Proceedings: Public Policy Aspects of High-Capacity Electric Power Transmission,* pages 2-105–2-131. EPRI WS-79-164, Electric Power Research Institute, Palo Alto, California. 312 pages.

Laidlaw, T.F. 1977. *The Camrose-Ryley Project Proposal (1975).* A Preliminary Assessment of the Surface Reclamation Potential on the Dodds-Roundhill Coal Field. Edmonton: Environment Conservation Authority. 97 pages.

McCready, R. 1979. Panel Presentation on "SO_2 Emissions – Effects on Water, Soil, Plants and Animals." In *Public Advisory Committee on the Environment. Proceedings of the 1979 Annual Joint Meeting with the Environment Council of Alberta,* pages 114-121. Edmonton: Environment Council of Alberta. 482 pages.

McCulloch, E. 1979. Panel Presentation on "SO_2 Emissions – Effects on Water, Soil, Plants and Animals." In *Public Advisory Committee on the Environment: Proceedings of the 1979 Annual Joint Meeting with the Environment Council of Alberta,* pages 121-129. Edmonton: Environment Council of Alberta. 482 pages.

MacDonald, W.R., and R.F. Klemm. 1973. *Selenium, Animal Health and Sour Gas Plants.* Edmonton: Environment Conservation Authority. 26 pages.

McGill, W.B., M.P. Nyborg, M.J. Rowell, J.A. Toogood, F.D. Cook, and D.H. Laverty. 1974. "Methods of Accelerating Oil Decomposition in Soil." In *Proceedings of a Workshop on Reclamation of Disturbed Lands in Alberta,* pages 118-137. Information Report Nor-X-116, Northern Forest Research Centre, Edmonton. 216 pages.

McKinnon, Allen and Associates (Western) Ltd. 1978a. *The Cost of Farming Around Transmission Line Towers in Central Alberta.* Calgary Power Ltd., Calgary. 84 pages.

----- 1978b. *A Summary of the Cost of Farming Around Transmission Line Towers in Central Alberta.* Calgary Power Ltd., Calgary. 17 pages.

Males, R. 1979. "High-Voltage Health Effects Studies." *EPRI Journal* 4(10): 57-59.

Marino, A.A., and R.O. Becker. 1978. "High Voltage Lines: Hazard at a Distance." *Environment* 20(9): 6-15.

Mayne, J.W. and J.F. Morrall. 1979. "The Edmonton-Calgary Corridor Transportation Study." *Canadian Journal of Civil Engineering* 6(2): 208-220.

Miller, M.W. and G.E. Kaufman. 1978. "High Voltage Overhead." *Environment* 20(1): 6-16.

Mudd, J.B. 1975. "Sulphur Dioxide." In *Responses of Plants to Air Pollution,* J.B. Mudd and T.T. Kozlowski, eds., pages 9-22. New York: Academic Press. 383 pages.

Nieboer, W. 1980. "Utility Corridors. Advantages – Disadvantages – Problems." Paper read at April 8, 1980 meeting of the Non-Renewable Resources Study Group of the Public Advisory Committee to the Environment Council of Alberta in Edmonton, Alberta.

Nyborg, M. 1974. "Reclamation of Soils and Waters Made Acid by Windblown Sulphur Dust." In *Proceedings of a Workshop on Reclamation of Disturbed Lands in Alberta,* pages 55-70. Information Report Nor-X-116, Northern Forest Research Centre, Edmonton. 216 pages.

Nyborg, M., A.C. Dick, J.M. Crepin, R.F. Klemm, J. Baker, and D. Hocking. 1975. "Current Results on Fate of Atmospheric SO_2 and Its Effects on Soil, Water and Vegetation." In *Proceedings of Alberta Sulphur Gas Research Workshop II,* pages 66-76. Alberta Department of the Environment and the University of Calgary. Edmonton: The Queen's Printer. 174 pages.

Nyborg, M., W.B. McGill, L.W. Carlson, and W.D. Holland. 1974. "Methods of Establishing Plant Growth After Heavy Oil Spills." In *Proceedings of a Workshop on Reclamation of Disturbed Lands in Alberta,* pages 138-150. Information Report Nor-X-116, Northern Forest Research Centre, Edmonton. 216 pages.

Nyborg, M. and D.R. Walker. 1977. "An Overview — The Effects of Sulphur Dioxide Emission on the Acidity and Sulphur Content of Soils." In *Proceedings of Alberta Sulphur Gas Research Workshop II,* pages 165-195. Alberta Department of the Environment and Alberta Institute of Pedology, Edmonton. 334 pages.

Ontario Ministry of Transportation and Communications. 1978. *Report on Technical Compatibility Criteria for Service Facilities in Multiple Use Rights-of-Way.* The Ministry of Transportation and Communications of Ontario. 47 pages.

Perry, E.R. 1979. "Overhead Transmission Lines." In *Workshop Proceedings: Public Policy Aspects of High-Capacity Electric Power Transmission,* pages 2-75—2-79. ESPI WS-79-164, Electric Power Research Institute, Palo Alto, California. 312 pages.

Peters, R.R. and H.S. Sandhu. 1980. *Nitrogen Oxide Emissions for Alberta.* RMO-80/3, Alberta Department of the Environment. 12 pages.

Pole, M.W., A. Bauer, L. Zimmerman, and S.W. Melsted. 1979. "Effects of Topsoil Thickness Placed on Spoilbanks on Wheat and Corn Yields in North Dakota." In *Proceedings Canadian Land Reclamation Association Fourth Annual Meeting,* pages 139-155. Canadian Land Reclamation Association, Guelph. 283 pages.

Railton, J. 1977. "Agricultural Potential of Reclaimed Lands." In *Proceedings Coal Industry Reclamation Symposium,* pages 33-46. The Coal Association of Canada, Calgary. 197 pages.

Red Deer Regional Planning Commission (RDRPC). 1978. *Communications and Utility Corridors.* Red Deer Regional Planning Commission, Red Deer. 24 pages.

----- 1979. *Economic Prospects.* Regional Planning and Research Section, Red Deer Regional Planning Commission, Red Deer. 69 pages.

----- 1980. *The PREP Survey.* Regional Planning and Research Section, Red Deer Regional Planning Commission, Red Deer. 40 pages.

----- 1981. *Proposed Regional Plan.* Red Deer Regional Planning Commission, Red Deer. 70 pages.

Rowell, M.J. 1977. "Oil Contaminated Soil and Some Aspects of Reclamation." In *Proceedings of 1977 Annual Alberta Soil Science Workshop on Soil Conservation, Reclamation and Research,* pages 150-166. Alberta Soil Science Workshop, Edmonton. 212 pages.

Sandhu, H.S. 1979. *Industrial Sulphur Emissions for Alberta 1974-1978.* Research Secretariat, Alberta Department of Environment. 21 pages.

Sandhu, H.S., H.P. Sims, R.A. Hursey, W.R. MacDonald, and B.R. Hammond. 1980. *Environmental Sulphur Research in Alberta: A Review.* Alberta Department of the Environment. 90 pages.

Schmidt Jr., R.H. 1980. "Freeway Impact on Agricultural Areas." *Natural Resources Journal* 20(3): 587-602.

Scott, W.S. 1981. "Economic Effects of Transmission Towers on Field Crops in Ontario." *Journal of Environmental Management* 12(2): 187-193.

Shah, K.R. 1979. *Review of State/Federal Environmental Regulations Pertaining to the Electrical Effects of Overhead Transmission Lines: 1978.* DOE/EV-0048/1, United States Department of Energy. 69 pages.

Shaneman R. 1977. "Problems and Techniques of Coal Mine Reclamation in the Prairie Context." In *Proceedings: Coal Industry Reclamation Symposium,* pages 98-107. The Coal Association of Canada, Calgary. 197 pages.

Shaw, D.M., D.E. Darby, and R.M. Trimmer. n.d. *The Lake Wabamun Thermal Water Project Final Report.* Alberta Department of Agriculture. 49 pages.

Shaw, D.R. n.d. "The Toxicity of Some Formation Fluids and Methods of Rehabilitation Subsequent to Their Spillage." Energy Resources Conservation Board, Calgary. 18 pages.

Stanley Associates Engineering Ltd. 1978. *Alberta Plains Coal Potential Plant Site Overview Study.* Alberta Department of Energy and Natural Resources. 3 vols.

Shipley, B.L. 1975. "Short and Long Term Effects of Sulphur Gas Emissions on Gray Wooded and Dark Gray Wooded Soils as Evidenced by Studies in the Whitecourt and Edson Regions of Alberta." In *Proceedings of Alberta Sulphur Gas Research Workshop II,* pages 84-93. Alberta Department of the Environment and the University of Calgary. Edmonton: The Queen's Printer. 174 pages.

Stewart, Weir, Stewart, Watson and Heinrichs (Consultants). 1974. *Corridors and Terminals. Athabasca Tar Sands Corridor Study,* Vol. 8. Alberta Department of the Environment. 220 pages.

Techman Ltd. 1977. *Materials Handling Methods for Plains Strip Mines.* Vol. 1. Alberta Department of Environment and the Coal Association of Canada, Calgary. 119 pages.

Toogood, J.A. 1974. "The Effect of Pipeline Installation on Crop Yield." In *Proceedings of a Workshop on Reclamation of Disturbed Lands in Alberta,* pages 15-18. Information Report Nor-X-116, Northern Forest Research Centre, Edmonton. 216 pages.

Toogood, J.A., and W.B. McGill. 1977. *The Reclamation of Agricultural Soils After Oil Spills. Part 2: Extension.* AIP Pub. No. M-77-11, The University of Alberta, Edmonton. 44 pages.

Williams, L.D. 1981. *Agricultural Impact Study. Concerns of Future Strip Mining in the Battle River Regional Planning Commission.* L.D. Williams Agricultural Services, Camrose, and Battle River Regional Planning Commission, Wetaskiwin. 109 pages.

Wacker, G. 1977. "Safety Considerations in Operating Sprinkler Irrigation Systems Near High-Voltage Transmission Lines." Appendix B in the ERCB report *In The Matter of a 240 kV Transmission Line Proposed by Calgary Power Ltd. Between Calgary and Lethbridge.* Energy Resources Conservation Board, Calgary.

Webber, H.J. and G.A. Warne. 1979. "Sulphur Emissions – Alberta Energy Industries." Paper read at a meeting of the Pacific North West International Section of the Air Pollution Control Association in Edmonton, Alberta.

Western Research and Development. 1978. *Derivation of First Order Estimates of Sulphur Deposition in the Region of Representative Point Sources.* Alberta Department of the Environment. 31 pages.

Yurko, W.J. 1974. "Population Distribution and Quality of Life." Address to the Second International Banff Conference on Man and His Environment. In *Policies, Programs and Proposals Relating to the Environment from Speeches of Hon. W.J. Yurko, Minister of Environment, Government of Alberta, 1971-1974,* pages 220-227. Edmonton: Environment Conservation Authority. 227 pages.

PERSONAL COMMUNICATIONS

Harrington, D. 1982. Land Reclamation Division, Alberta Environment. Edmonton.

Nieboer, W. 1982. TransAlta Utilities Corporation. Calgary.

STATUTES AND REGULATIONS

The Coal Conservation Act. RSA 1980, cC-14

The Energy Resources Conservation Act. RSA 1980, cE-11

The Land Surface Conservation and Reclamation Act, RSA 1980, cL-3

The Oil and Gas Conservation Act. RSA 1980, cO-5

The Planning Act Subdivision Regulation, Alta. Reg. 132/78.

The Public Highways Development Act. RSA 1980, cP-28

The Surface Rights Act. RSA 1980, cS-27

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